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PART I

Pilot Test Work Plan for Four Additional Bioventing Sites Hill Air Force Base, Utah

PART II

Draft Interim Pilot Test Results Report for Four Additional Bioventing Sites Hill Air Force Base, Utah

Prepared For

Air Force Center for Environmental Excellence
Brooks AFB, Texas

and

Ogden Air Logistics Center/EMR
Hill Air Force Base, Utah

ES
Engineering-Science, Inc.

1700 BROADWAY, SUITE 900 DENVER, COLORADO 80290

March 1994

AQ M01-02-0378

ES ENGINEERING-SCIENCE

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PART I
PILOT TEST WORK PLAN
FOR FOUR ADDITIONAL BIOVENTING SITES
HILL AIR FORCE BASE, UTAH

Prepared for:

Air Force Center for Environmental Excellence
Brooks Air Force Base, Texas

and

Ogden Air Logistics Center/EMR
Hill Air Force Base, Utah

by

Engineering-Science, Inc.
1700 Broadway, Suite 900
Denver, Colorado

March 1994

A7-4-18

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FIGURES

PART I

PILOT TEST WORK PLAN FOR FOUR ADDITIONAL BIOVENTING SITES HILL AFB, UTAH

1.0 INTRODUCTION

This work plan presents the scope of *in situ* bioventing pilot tests for treatment of fuel- and solvent-contaminated soils at four sites on Hill Air Force Base (AFB), Utah. The subject sites include sites 388, 510.8, 1705, (Figure 1.1) and 40002 (Figure 1.2). The pilot tests have three primary objectives: 1) to assess the potential for supplying oxygen throughout the contaminated soil depth, 2) to determine the rate at which indigenous microorganisms will degrade fuel when stimulated by oxygen-rich soil gas, and 3) to evaluate the potential for sustaining these rates of biodegradation until fuel contamination is remediated to concentrations below regulatory standards.

These pilot tests will be conducted in two phases. The initial phase of the project will consist of construction of vent wells (VWs) and vapor monitoring points (MPs), *in situ* respiration tests, and air permeability tests. Construction and initial testing are expected to take approximately four weeks. This duration is brief due to some site VWs and PMs having already been installed. Also, electricity has already been installed at several of these sites. During the second phase, pilot-scale bioventing systems will be installed at each site and monitored over a 1-year period. This work will be completed by Engineering-Science, Inc. (ES) personnel from both our Denver and Salt Lake City office.

If bioventing proves to be an effective means of remediating soils at these sites, pilot test data may be used to design full-scale remediation systems and to estimate the time required for site cleanup. An added benefit of the pilot testing at these sites is that a significant amount of the fuel contamination should be biodegraded during the 1-year pilot tests, as the testing will take place within highly contaminated soils at these sites.

Additional background information on the development and recent success of the bioventing technology is found in the reference document entitled *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing* (Hinchee et al., 1992). This protocol document will also serve as the primary reference for detailed procedures that will be used during the pilot test.

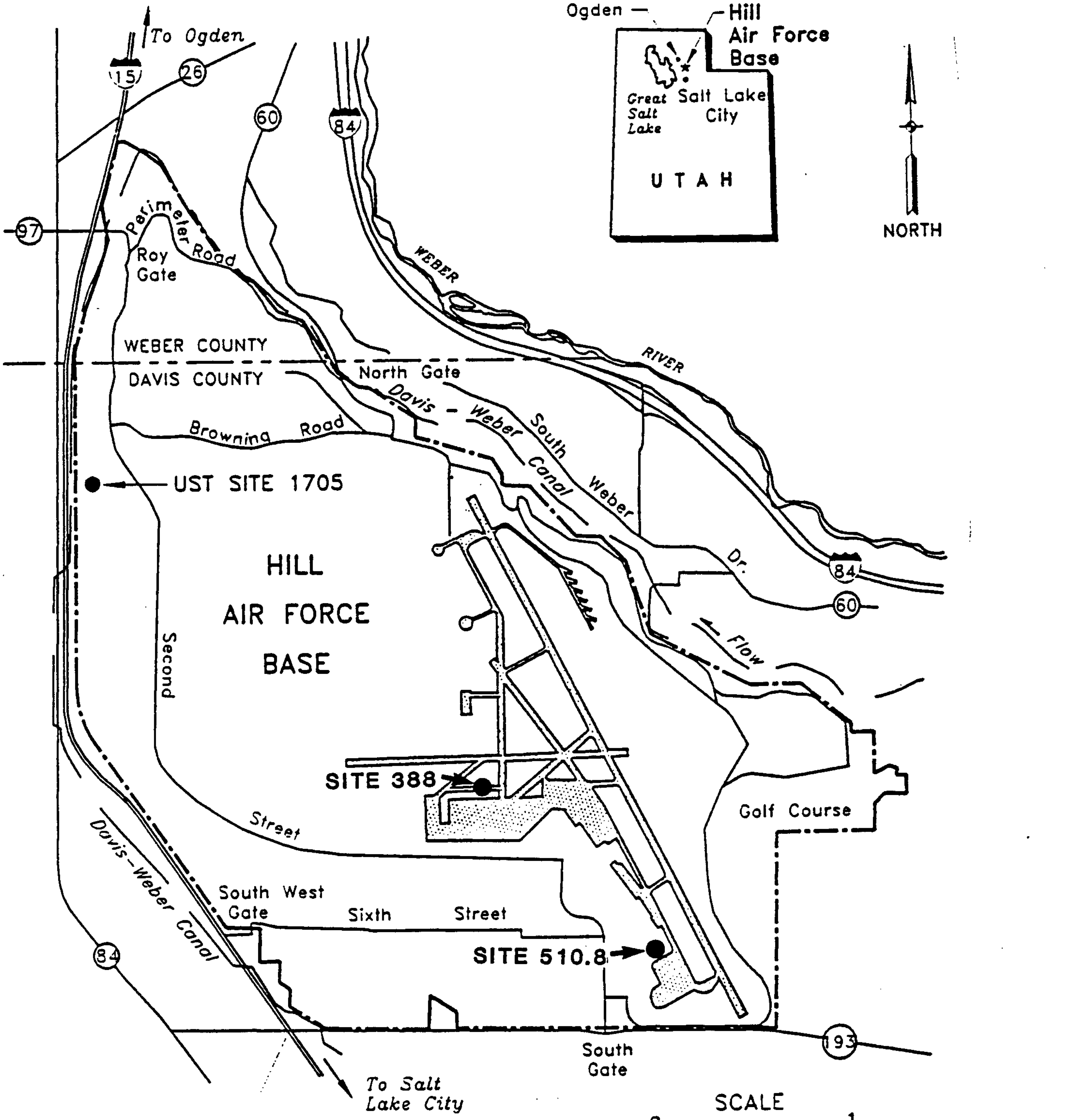

FIGURE 1.1

LOCATIONS OF SITES 388, 510.8, AND 1705 WITH RESPECT TO BASE

Hill AFB, Utah

ENGINEERING-SCIENCE, INC.

Denver, Colorado

Source: Radian Corporation, 1993.

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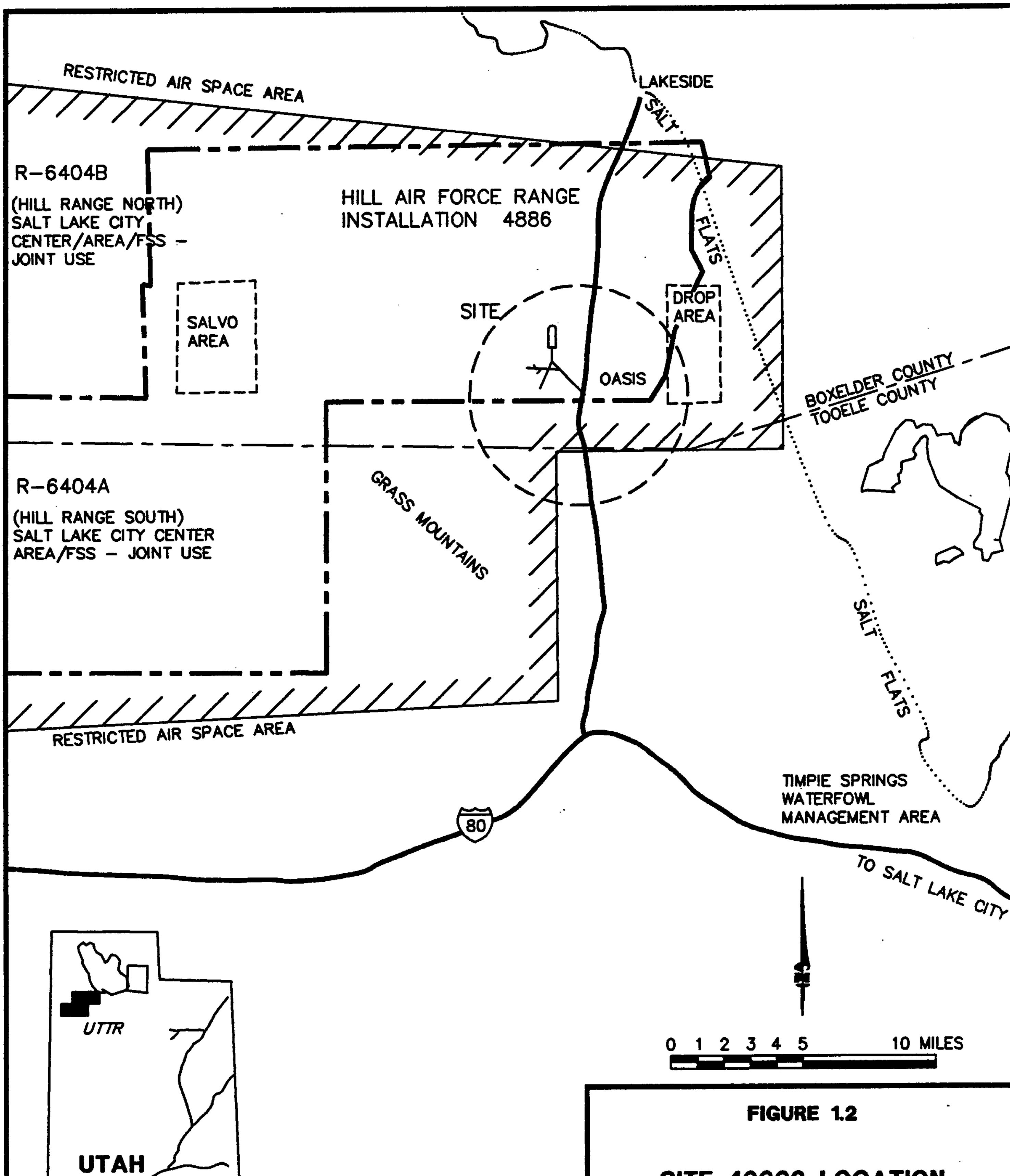


FIGURE 1.2

SITE 40002 LOCATION

Hill AFB UTTR, Utah

ENGINEERING-SCIENCE, INC.

Denver, Colorado

SOURCE:
ENGINEERING-SCIENCE, INC. 1993

2.0 SITE DESCRIPTIONS

2.1 Site 388

2.1.1 Site Location and History

The location of Site 388 with respect to the base is shown in Figure 1.1. Site 388 is located north of Hangar 45 in a grassy area approximately 350 feet west of taxiway 3 and south of Tank Storage Area 5053. Figure 2.1 shows the layout of Site 388.

A 2,300-gallon underground concrete vault, formerly containing waste JP-4 fuel, was permanently closed on December 10, 1987. Hydrocarbon contamination was detected in soil samples collected following vault removal. A total of six soil borings were drilled in July 1992. Three of the soil borings were converted to MPs, one was converted to a VW, and two were abandoned. The locations of the three MPs, the VW, and the two abandoned soil borings are shown in Figure 2.1. (EA Engineering, Science, and Technology, 1992a).

2.1.2 Site Geology and Extent of Contamination

Because the bioventing technology is applied to unsaturated soils, this section primarily addresses soils above the groundwater table. At Site 388, groundwater occurs at a depth greater than 150 feet, and flows in a generally westwardly direction. It is not believed to be affected by contamination from the former UST at this site (EA Engineering, Science, and Technology, 1992a).

Soils at Site 388 consist of silty sands and thin layers of sandy gravels. Bioventing is easily applied to these coarse-grained soils because there is more available pore space for soil gas flow. Engineering-Science, Inc. (ES) has completed successful bioventing projects in similar soils, and is confident that oxygen can be distributed through these soils. The soil vapor MPs will be used to examine the subsurface oxygen pattern in the different soil depths and layers during the pilot test.

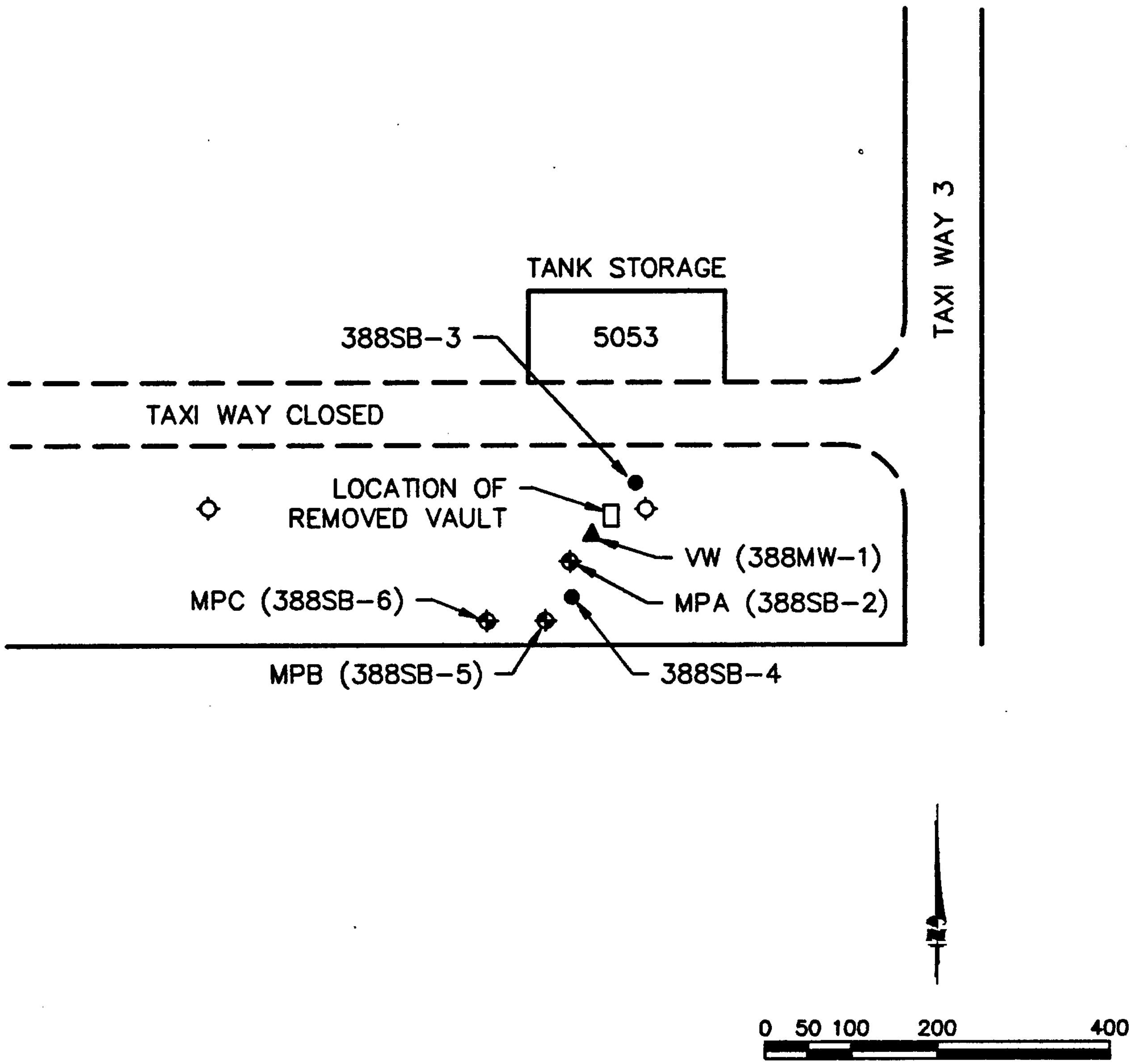
The primary contaminants at this site are JP-4 fuel residuals which have migrated to a depth greater than 100 feet, and laterally at least 130 feet to the south-southwest. Soil sample analyses yielded total petroleum hydrocarbon (TPH) concentrations ranging from nondetected [less than 10 milligrams per kilogram (mg/kg)] to 16,800 mg/kg. Benzene, toluene, ethylbenzene, and xylenes (BTEX) and naphthalene were also detected at Site 388 (EA Engineering, Science, and Technology, 1992a).

2.2 Site 510.8

2.2.1 Site Location and History

The location of Site 510.8 with respect to the base is shown in Figure 1.1. Site 510.8 is located south of Building 510 near the southwest corner of the building. Figure 2.2 shows the location of Site 510.8 in relation to Building 510.

A 2,000-gallon underground storage tank (UST), formerly containing Stoddard® solvent, was removed in 1989. Hydrocarbon contamination was detected in soil samples collected following UST removal. A total of five soil borings were drilled in January 1991 and July 1992. Two of the soil borings were completed as groundwater monitoring wells. One of the monitoring wells, 5105VE-1 will be used as the VW for



LEGEND

- ● SOIL BORING
- ⊕ EXISTING MONITORING POINT
- ▲ EXISTING AIR INJECTION VENT WELL
- ◇ LIGHT POLE

Source:
EA Engineering, Science, and Technology, 1992a

FIGURE 2.1

SITE 388 LAYOUT

Hill AFB, Utah

ENGINEERING-SCIENCE, INC.

Denver, Colorado

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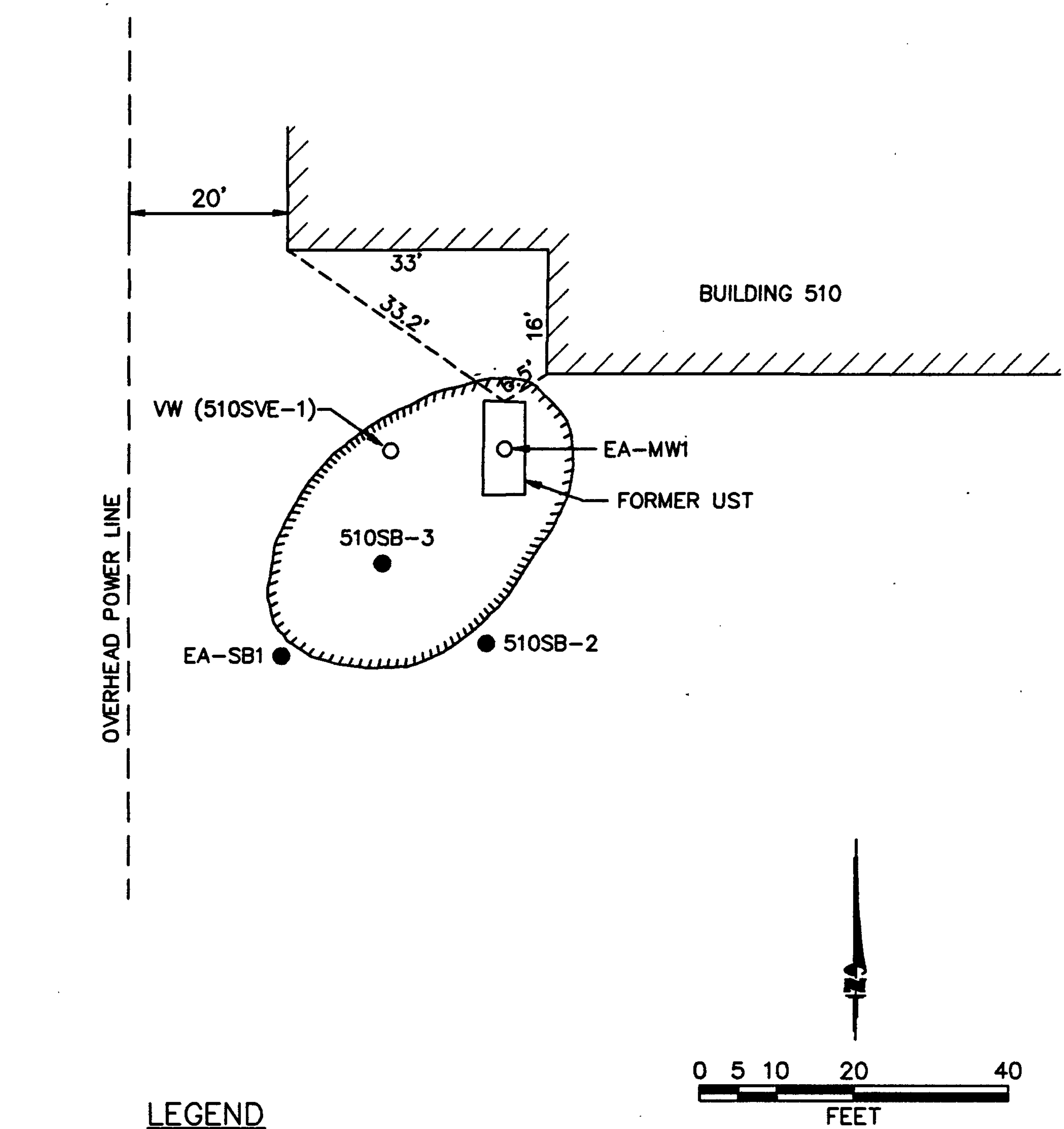

LEGEND

BOUNDARY OF CONTAMINATED SOIL

SOIL BORING

EXISTING MONITORING WELL

FIGURE 2.2

SITE 510.8 LAYOUT AND EXTENT OF CONTAMINATION

Hill AFB, Utah

ENGINEERING-SCIENCE, INC.

Denver, Colorado

Source:
EA Engineering, Science, and Technology 1992b

93DN0427, 05/03/93 at 11:34

the bioventing pilot testing (Figure 2.2) (EA Engineering, Science, and Technology, 1992b).

2.2.2 Site Geology and Extent of Contamination

Soils at Site 510.8 consist of sand and silty sand with numerous discrete clay layers in the sandy portions of the section between 27 and 80 feet below ground surface (bgs). Groundwater occurs at approximately 85 feet bgs, and is not believed to be affected by contamination from the former UST at this site (EA Engineering, Science, and Technology, 1991).

The primary contaminants at this site are Stoddard® solvent residuals which are present to a depth of at least 52 feet, and laterally approximately 30 feet to the southwest (Figure 2.2). Soil sampling yielded TPH (as Stoddard® solvent) concentrations ranging from nondetected (less than 10 mg/kg) to 11,400 mg/kg (EA Engineering, Science, and Technology, 1992b).

2.2.3 Initial Soil Gas Characterization

Initial soil gas samples from Site 510.8 were collected and analyzed by ES on March 2, 1993. Carbon dioxide was present at an elevated concentration (13.1%), and oxygen was present at a depleted level (0.8%), indicating the presence of biological activity in the soils and suggesting that bioventing may be a feasible technology for site remediation.

2.3 Site 1705

2.3.1 Site Location and History

The location of Site 1705 with respect to the base is shown in Figure 1.1. Site 1705 is located immediately east of Building 1705 near the Tooele Rail Shop, which is an industrial area, in the western section of Hill AFB (Figure 2.3). Figure 2.4 shows the location of Site 1705 in relation to Building 1705. The majority of the site is covered with buildings and asphalt paving.

Two 1,000-gallon USTs, designated tanks 1705.1 and 1705.2, were removed from Site 1705 on March 11, 1992. Tank 1705.1 formerly contained diesel fuel, and tank 1705.2 contained leaded gasoline. A total of four borings were drilled by Radian Corporation in November 1992. The borings were completed as one groundwater monitoring well, one air injection VW, and two soil vapor probe installations to be utilized by ES as MPs (Figure 2.4)(Radian Corporation, 1993).

2.3.2 Site Geology and Extent of Contamination

Soils at Site 1705 consist of moderately to well-sorted sand with some silt and silty sand. Groundwater is encountered at approximately 25 feet bgs. Petroleum hydrocarbon contamination was not detected in a groundwater sample collected from MW-1 (Radian Corporation, 1993).

Contamination at Site 1705 is believed to be limited to the southwestern corner of the former UST excavation. The primary contaminants at this site are diesel fuel residuals which have migrated to a depth of approximately 23 feet bgs. Soil sampling yielded a TPH concentration of 13,200 mg/kg at 10 feet bgs in the VW. Benzene,

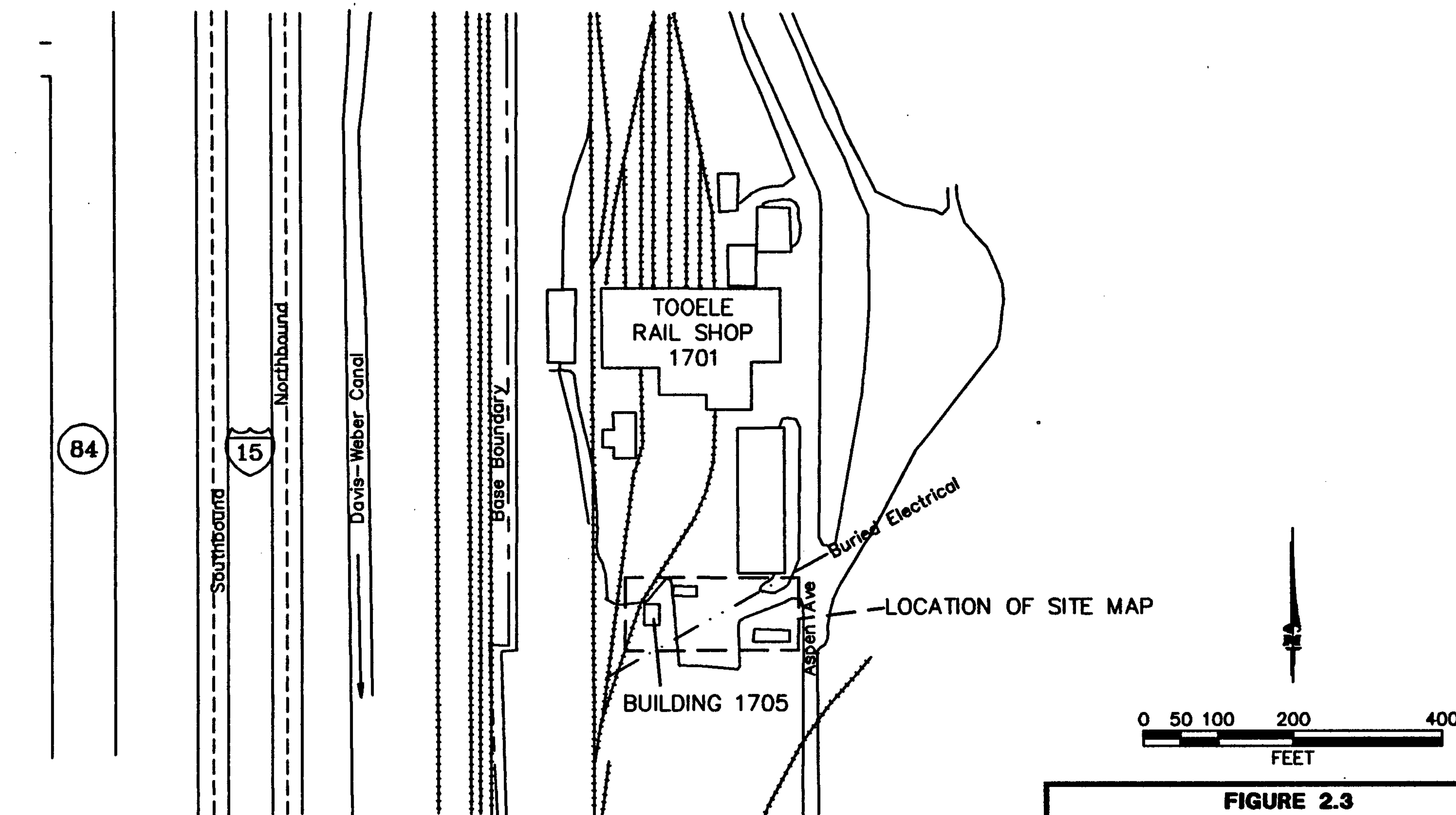

FIGURE 2.3

SITE 1705 LOCATION

Hill AFB, Utah

ENGINEERING-SCIENCE, INC.
Denver, Colorado

Source: Radian Corporation, 1993

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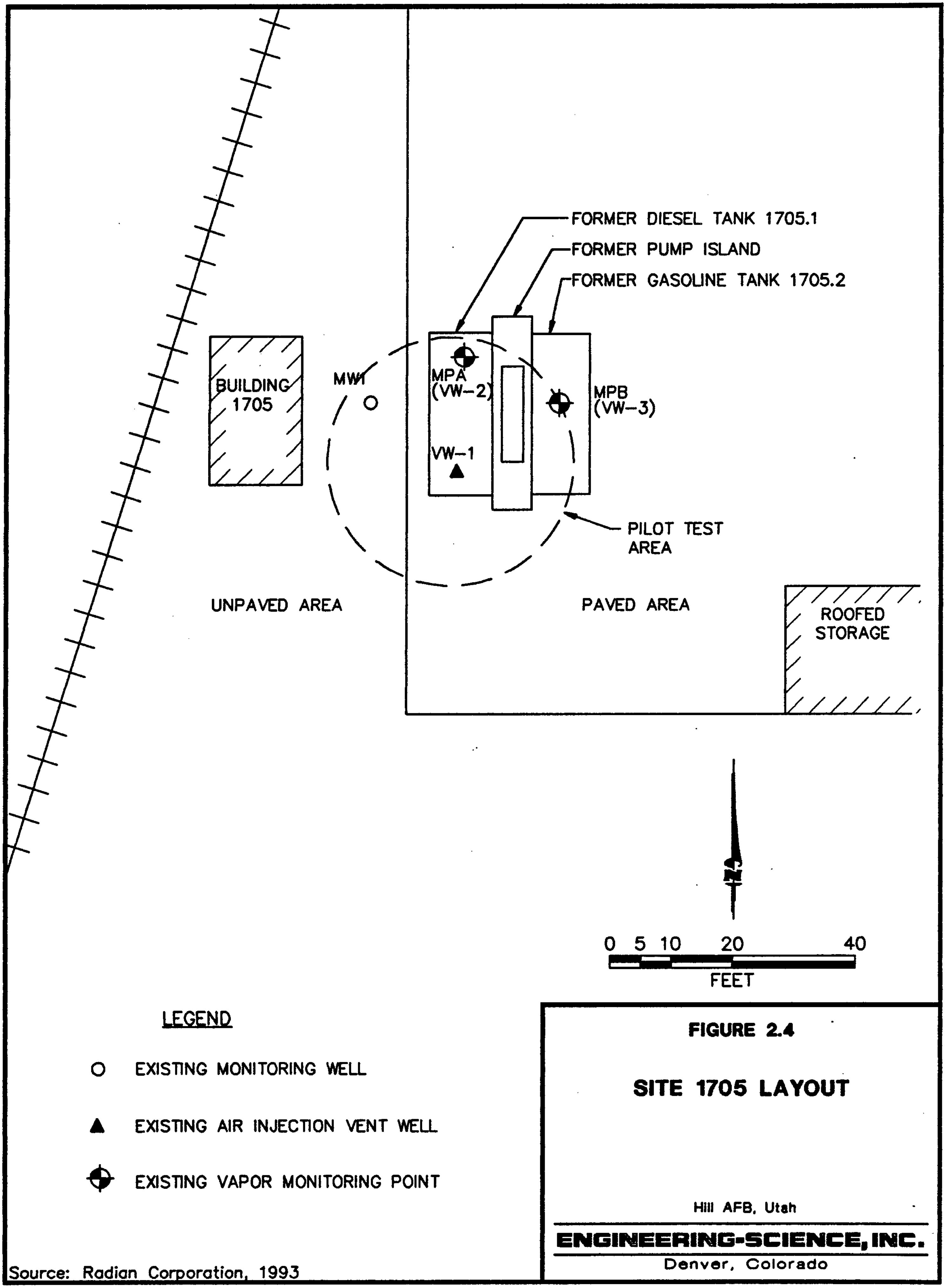


Source: Radian Corporation, 1993

FIGURE 2.4

SITE 1705 LAYOUT

Hill AFB, Utah

ENGINEERING-SCIENCE, INC.
Denver, Colorado

93DN0386, 05/04/93 at 10:51

toluene, ethylbenzene, and xylenes (BTEX) and naphthalene were also detected in the southwest corner of the former UST excavation (Radian Corporation, 1993).

2.4 Site 40002

2.4.1 Site Location and History

Site 40002, is located at the Hill AFB Utah Test and Training (UTTR) facility, Utah. The UTTR is an off-base facility operated by Hill AFB. The UTTR is located on the west side of Great Salt Lake in Box Elder County. The military town of Oasis, where UST Site 40002 is located, is approximately 50 miles west of Hill AFB. The site is approximately 20 miles north of Interstate 80, Exit 62. Site 40002 is located on the northeast side of the UTTR complex, as shown in Figure 1.2. The Site 40002 layout is shown in Figure 2.5.

Three USTs were removed from Site 40002. Tank 40002.1 was a 30,000-gallon steel UST containing diesel fuel. Tank 40002.2 was a 25,000-gallon steel UST containing unleaded mogas. Tank 40002.3 was a 12,000-gallon fiberglass reinforced plastic (FRP) UST containing unleaded mogas. The three tanks were last used in May 1992. The two steel tanks were used exclusively to store their respective products and were in operation for approximately 12 years. The FRP tank was a replacement tank for a steel tank that had manufacturing defects. UTTR Civil Engineering staff indicated the steel tank that had been replaced did not leak or show signs of leaking. The FRP tank was used exclusively for unleaded mogas and was in operation for approximately 10 years. Petroleum products from the past operations were detected in the soils when the USTs and associated piping were removed on June 3, 1992 (Engineering-Science, Inc. 1993).

2.4.2 Site Geology and Extent of Contamination

Soils at Site 40002 consist of primarily sand and silt with some clay. A number of soil borings were installed at this site. Soil borehole SB-6 contained fill material to a depth of approximately 14 feet bgs, underlain by a layer of clay and interbedded layers of sand, silt, and clay. Soil borings 6, 8, and 9 were completed as MPA, VW, and MPB respectively (Figure 2.5).

The primary contaminants at this site are fuel residuals which have migrated to a depth of at least 47.5 feet bgs. Contamination appears to localized, extending outward from the former UST locations approximately 10 feet. Soil sampling yielded TPH concentrations ranging from nondetected (less than 10 mg/kg) to 60,600 mg/kg. BTEX and naphthalene were also detected at Site 40002 (Engineering-Science, Inc., 1993).

3.0 SITE-SPECIFIC ACTIVITIES

The purpose of this section is to describe the work that will be performed by ES at each of the four bioventing sites at Hill AFB. VWs and vapor MPs have already been installed at three of the sites by other contractors. Therefore, drilling will be performed only at Site 510.8. Activities that will be performed at each site include *in situ* respiration tests, an air permeability test, and the installation of a long-term bioventing system.

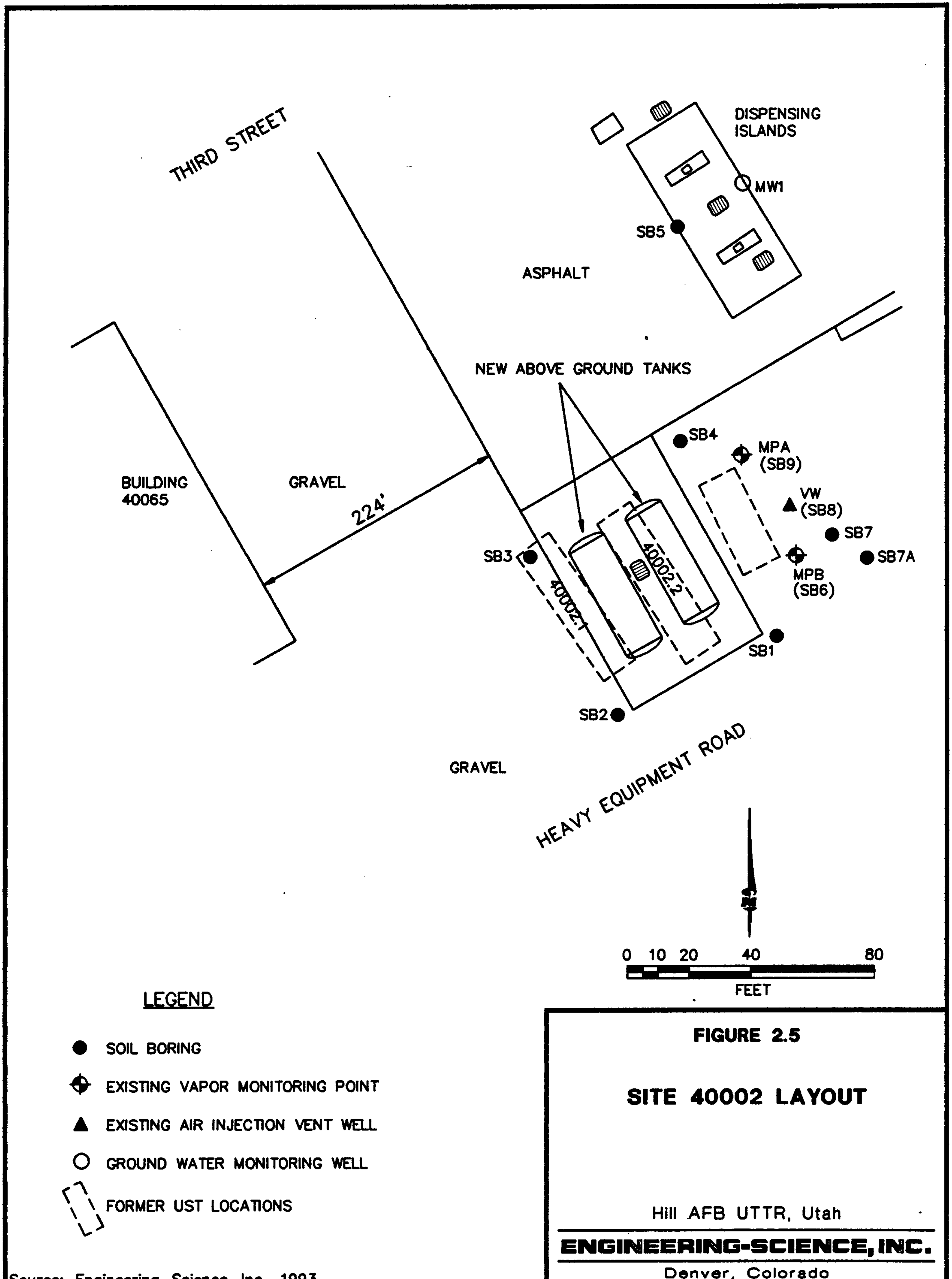


FIGURE 2.5

SITE 40002 LAYOUT

Hill AFB UTTR, Utah

ENGINEERING-SCIENCE, INC.

Denver, Colorado

93DN0388, 05/03/93 at 11:46

3.1 Layout of Pilot Test Components

3.1.1 Site 388

Figure 2.1 indicates the locations of the existing VW and MPs at Site 388. The VW is screened from 25 to 75 feet bgs. MPA is screened at depth intervals of 50 feet, 75 feet, and 90 feet bgs. MPB and MPC are screened at a depth interval of 94 feet bgs. Soils in this area are expected to be oxygen depleted (<2%) due to high hydrocarbon levels, and increased biological activity should be stimulated by oxygen-rich soil gas ventilation during pilot test operations.

Due to the coarse-grained composition of the sandy soils at this site and the experience that ES has had with similar soil types at Hill AFB, the potential radius of influence around the central VW is expected to be at least 40 feet. Vapor MP, MPA, is within 40 feet. Two vapor MPs (MPB and MPC) are located within an approximate 160-foot radius of the VW (Figure 2.1). These two MPs may not be useful for the permeability test, however, they will be used in the respiration test.

3.1.2 Site 510.8

Figure 3.1 indicates the proposed locations of the VW and MPs at the primary pilot test location at Site 510.8. The VW is already installed at the indicated location. The final locations of the MPs may vary slightly from the proposed locations. Soils in the vicinity of the existing VW are oxygen depleted (<2%) due to high hydrocarbon levels, and increased biological activity should be stimulated by oxygen-rich soil gas ventilation during pilot test operations.

Due to the coarse-grained composition of these sandy soils at this site and the experience that ES has had with similar soil types at Hill AFB, the potential radius of influence around the central VW is expected to be approximately 35 to 40 feet. Three vapor MPs (MPA, MPB and MPC) will be located within a 40-foot radius of the VW (Figure 3.1).

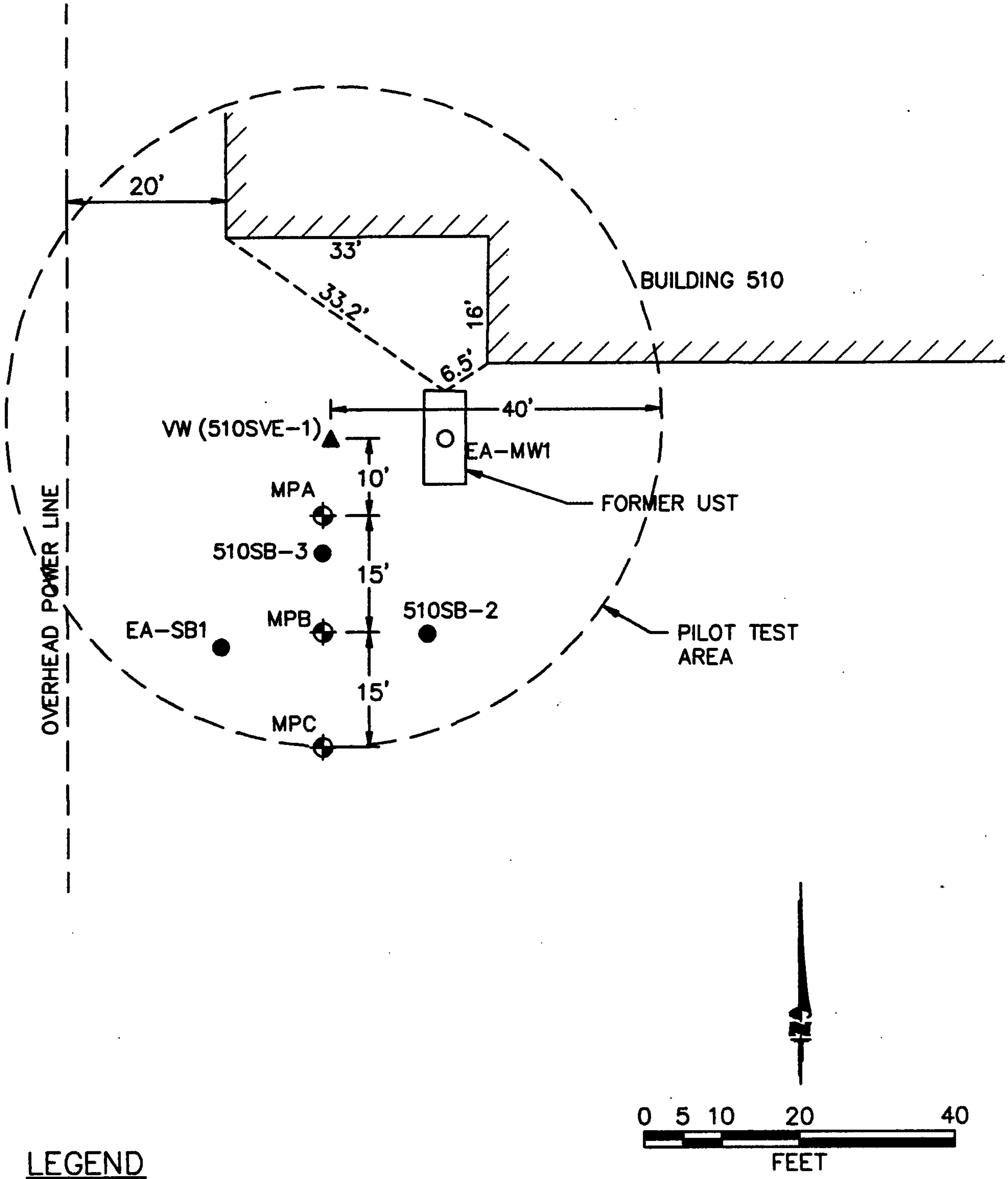
3.1.3 Site 1705

Figure 2.4 indicates the locations of the existing VW and MPs at Site 1705. The VW was drilled to a total depth of 23 feet bgs, 2 feet above the water table. MPA is screened at a depth of 13 feet bgs. MPB is screened at a depth of 15.4 feet bgs. The MPs are located within approximately 20 feet of the VW. Soils in this area are expected to be oxygen depleted (<2%) due to high hydrocarbon levels, and increased biological activity should be stimulated by oxygen-rich soil gas ventilation during pilot test operations.

Due to the coarse-grained composition of these sandy soils at this site and the experience that ES has had with similar soil types at Hill AFB, the potential radius of influence around the central VW is expected to be greater than 20 feet, possibly 40 feet, however, due to site characterization considerations, vapor MPs, MPA and MPB, were placed only within an approximate 20-foot radius of the VW (Figure 2.4).

3.1.4 Site 40002

Figure 2.5 indicates the locations of the existing VW and MPs at Site 40002. The VW (SB-8) is screened from 5 to 45 feet bgs. MPA (SB6) and MPB (SB9) are within



LEGEND

- SOIL BORING
- EXISTING MONITORING WELL
- EXISTING AIR INJECTION VENT WELL
- PROPOSED MONITORING POINT

Source: EA Engineering, Science, and Technology, 1992b

FIGURE 3.1

**SITE 510.8
INJECTION VENT WELL
AND PROPOSED MONITORING
POINT LOCATIONS**

Hill AFB, Utah

ENGINEERING-SCIENCE, INC.
Denver, Colorado

25 feet of the VW and are screened at depth intervals of 16.5 feet to 17.5 feet and 30 to 32 feet bgs. Soils in this area are expected to be oxygen depleted (<2%) due to high hydrocarbon levels, and increased biological activity should be stimulated by oxygen-rich soil gas ventilation during pilot test operations.

Due to the coarse-grained composition of these sandy soils at this site and the experience that ES has had with similar soil types at Hill AFB, the potential radius of influence around the central VW is expected to be greater than 25 feet, possibly 40 feet, however, due to site characterization considerations, vapor MPs, MPA and MPB, were placed only within an approximate 25-foot radius of the VW (Figure 2.5).

3.2 Vent Wells

3.2.1 Site 388

The VW at Site 388 is constructed of 2-inch inside-diameter (ID) schedule 80 polyvinyl chloride (PVC) casing, with a 50-foot interval of 0.02-inch slotted screen set at 25 to 75 feet bgs. The filter pack is well-rounded silica sand with an 8 grain size, and was placed in the annular space of the screened interval. A 2-foot layer of bentonite was placed directly over the filter pack. The remaining annular space was then filled with bentonite/cement grout to the ground surface. A complete seal is critical to prevent injected air from short-circuiting to the surface during the bioventing test. See Appendix A for the VW well completion form (Well 388MW-1/SVE-1).

3.2.2 Site 510.8

The VW at Site 510.8 is constructed of 2-inch ID schedule 40 PVC casing, with a 30-foot interval of 0.02-inch slotted screen set at 34 to 64 feet bgs. The filter pack is well-rounded silica sand with an 8 grain size, and was placed in the annular space of the screened interval. A 2-foot layer of bentonite was placed directly over the filter pack. The remaining annular space was then filled with bentonite/cement grout to the ground surface. See Appendix A for the VW well completion form (Well 510SVE-1).

3.2.3 Site 1705

The VW at Site 1705 is constructed of 4-inch ID schedule 40 PVC casing, with a 10-foot interval of 0.02-inch slotted screen set at 10.0 to 19.5 feet bgs. The filter pack is well-rounded silica sand with a 10-20 grain size, and was placed in the annular space of the screened interval. A 1.5-foot layer of bentonite was placed directly over the filter pack. The remaining annular space was then filled with bentonite/cement grout to the ground surface. See Appendix A for the VW well completion form (Well T17051VW).

3.2.4 Site 40002

The VW at Site 40002 is constructed of 4-inch ID schedule 40 PVC casing, with a 40-foot interval of 0.02-inch slotted screen set at 5 to 45 feet bgs. The filter pack is well-rounded number 8 quartz sand, and was placed in the annular space of the screened interval. The remaining annular space was then filled with bentonite/cement grout to the ground surface. See Appendix A for the VW well completion form.

3.3 Vapor Monitoring Points

3.3.1 Site 388

At Site 388, 388SB-2, 388SB-5, and 388SB-6 will be used as multidepth vapor MPs (MPA, MPB, and MPC). Well 388SB-2 is screened at depth intervals of 50, 75, and 90 feet bgs. Wells 388SB-5 and 388SB-6 are screened at a depth of 94 feet bgs. The construction details are illustrated in Appendix A. Soil gas oxygen and carbon dioxide concentrations will be monitored with the vapor probes installed at the indicated depth intervals. Multidepth monitoring will confirm that the entire contaminated soil profile is receiving oxygen, and will allow measurement of fuel biodegradation rates at three depths.

3.3.2 Site 510.8

A typical vapor MP installation for Site 510.8 is shown in Figure 3.2. Three MPs (MPA, MPB, and MPC) will be installed at Site 510.8 during initial pilot test field activities. Soil gas oxygen and carbon dioxide concentrations will be monitored with vapor probes installed at depth intervals of approximately 20, 35, and 50 feet bgs at each MP location. Soil temperature will be monitored using thermocouples installed at depths of 20 feet and 50 feet bgs at MPA only. The exact depth of each MP will be determined based on the interval of highest contamination. Vapor probes are constructed of 6-inch-long sections of 1-inch-diameter PVC well screen with 0.25-inch-diameter schedule 80 PVC riser pipe. Each vapor probe will be placed within a 1- to 1.5-foot layer of 6-9 silica sand.

Multidepth monitoring will confirm that the entire contaminated soil profile is receiving oxygen, and will allow measurement of fuel biodegradation rates at the two depths. The annular space between these three intervals will be sealed with bentonite to isolate the intervals. The bentonite seals will consist of bentonite pellets or granular bentonite hydrated in place. The bentonite within 2 feet above and below the sand packs will be placed in approximately 6-inch-thick layers to assure complete saturation and hydration of the bentonite before placement of subsequent layers. Additional details on MP construction are presented in Section 4 of the protocol document (Hinchee et al., 1992).

3.3.3 Site 1705

Two existing wells (VW-2 and VW-3) will be used as MPs at Site 1705. Well VW-2 (MPA) is screened using 1.5 inch diameter slotted PVC screen in 10-20 grain sand from a depth of 11.5 to 13 feet bgs. Well VW-3 (MPB) is screened using 1.5 inch diameter slotted PVC screen in 10-20 grain sand from a depth of 13.9 to 15.4 feet. See Appendix A for the borehole logs and MP construction details.

3.3.4 Site 40002

Again, two existing wells (SB-6, and SB-9) will be used as MPs at Site 40002. Well SB-9 (MPA) and SB-6 (MPB) are completed as vapor MPs with screened intervals from 16.5 to 17.5 feet and 30 to 32 feet bgs. Intervals are 1.5 inch I.D. PVC screen. See Appendix A for the MP completion forms.

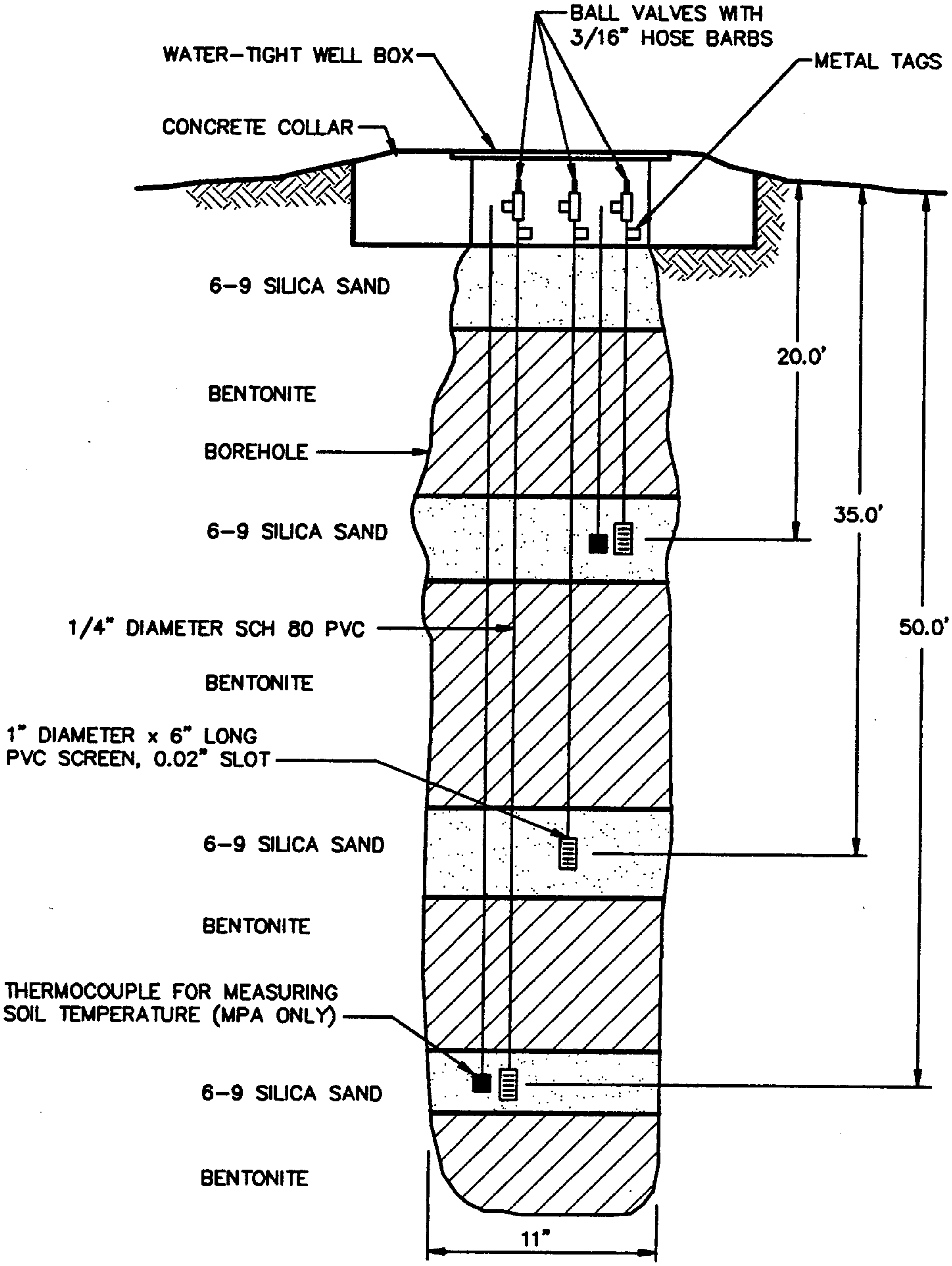


FIGURE 3.2

SITE 510.8
PROPOSED MONITORING POINT CONSTRUCTION DETAIL

Hill AFB, Utah

ENGINEERING-SCIENCE, INC.

Denver, Colorado

93DN0432, 05/03/93 at 12:07

3.4 Handling of Drill Cuttings

Drilling will be required only for installation of MPs at Site 510.8. Cuttings will be collected in U.S. Department of Transportation (DOT) approved containers. The containers will be labeled and staged on pallets at the site. Drill cuttings will become the responsibility of Hill AFB, and will be analyzed, handled, and disposed of in accordance with the current procedures for ongoing remedial investigations. This bioventing pilot test project is expected to generate approximately fifteen 55-gallon drums of drill cuttings.

3.5 Soil and Soil Gas Sampling

3.5.1 Soil Samples

Three soil samples will be collected from Site 510.8 during the installation of the three MPs. Sampling procedures will follow those outlined in the protocol document. One sample will be collected from the most contaminated interval of each of the MPs. Soil samples will be analyzed for total recoverable petroleum hydrocarbons (TRPH), BTEX, soil moisture, pH, particle sizing, alkalinity, total iron, and nutrients.

Samples for TRPH and BTEX analyses will be collected using a split-spoon sampler containing brass tube liners. Soil samples collected in the brass tubes will be immediately trimmed, and the ends of the tubes will be sealed with aluminum foil or Teflon® fabric held in place by plastic caps. Soil samples collected for physical parameter analyses will either be collected and handled in the same manner as TRPH and BTEX samples, or placed into glass sample jars. Soil samples will be labelled following the nomenclature specified in the protocol document (Section 5), wrapped in plastic, and placed in a cooler for shipment. A chain-of-custody form will be filled out, and the cooler will be shipped to the Pace/ES Laboratory in Berkeley, California, for analysis. This laboratory has been audited by the Air Force and meets all quality assurance/quality control and certification requirements for the State of California.

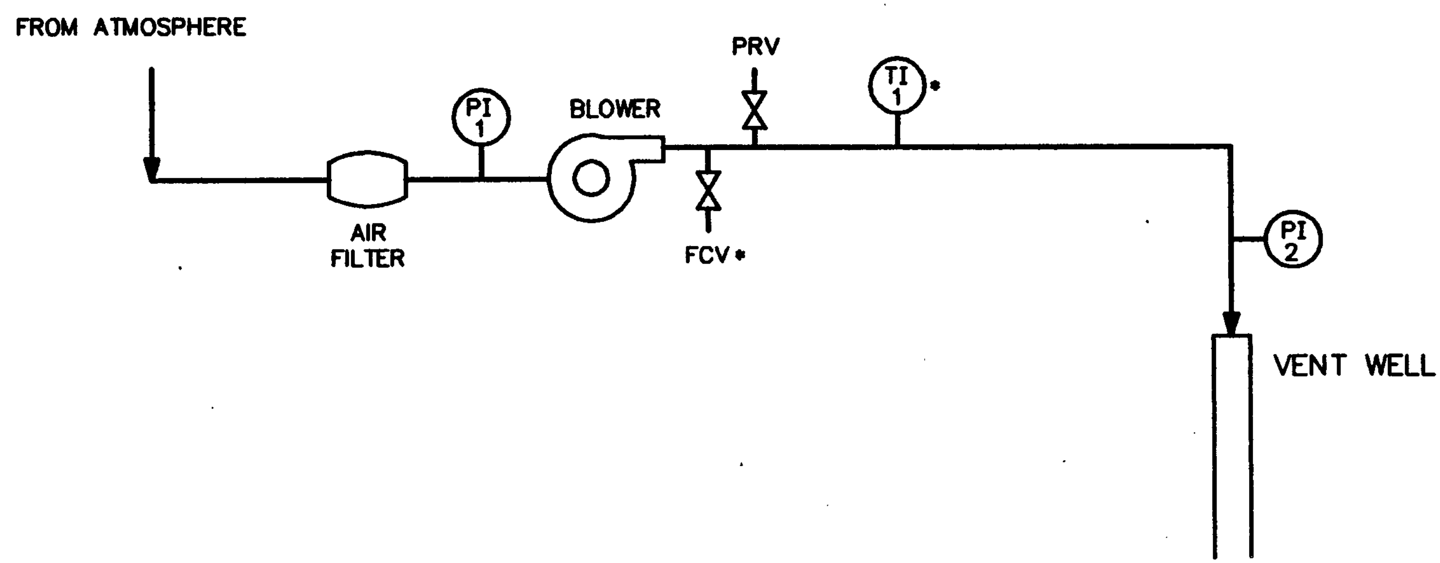
3.5.2 Soil Gas Samples

At each site, initial and final pilot test soil gas samples will be collected in SUMMA® canisters in accordance with the *Field Sampling Plan* (Engineering-Science, Inc., 1992) from the VW and from the MPs closest to and furthest from the VWs (MPA and MPB or C). Additionally, these soil gas samples will be used to determine the reduction in BTEX and total volatile hydrocarbons (TVH) during the 1-year test, and to detect migration of these vapors from the source areas.

Soil gas sample canisters will be placed in a small cooler and packed with foam pellets to prevent excessive movement during shipment. Samples will not be sent on ice to prevent condensation of hydrocarbons. A chain-of-custody form will be filled out, and the cooler will be shipped to the Air Toxics, Inc. laboratory in Rancho Cordova, California for analysis.

3.6 Blower Systems

A 3-horsepower regenerative blower capable of injecting 30 cubic feet per minute (cfm) at 12 pounds per square inch (psi) will be used to conduct the initial air permeability tests at each site. Figure 3.3 is a schematic of a typical air injection



LEGEND

PI 1 PRESSURE INDICATOR

TI 1 TEMPERATURE INDICATOR

FCV FLOW CONTROL VALVE

PRV PRESSURE RELIEF VALVE

* OPTIONAL

FIGURE 3.3

BLOWER SYSTEM INSTRUMENTATION DIAGRAM FOR AIR INJECTION

Hill AFB, Utah

ENGINEERING-SCIENCE, INC.

Denver, Colorado

93DN0426 05/03/93 at 12:09

system used for pilot testing. The maximum power requirement anticipated for these pilot tests is 230-volt, single-phase, 30-amp service.

At Site 388, the base is requested to provide a breaker box with (1) 110-volt/single-phase/50-amp power, and two 110-volt receptacles (with one receptacle supplying 20-amp power), or preferably, (2) 230-volt/single-phase/30-amp power, and one 230-volt receptacle.

At Sites 510.8, 1705, and 40002, a licensed electrician subcontracted to ES will perform necessary powerline trenching, piping, and connections to existing power sources. This electrician will assist in wiring the blower to line power in each of the four sites. Additional details on power supply requirements are described in Section 5.0, Base Support Requirements.

3.7 In Situ Respiration Test

The objective of the *in situ* respiration test is to determine the rate at which soil bacteria degrade petroleum hydrocarbons. Section 5.7 of the protocol document describes the procedures to be used (Hinchee et al., 1992). At each site, respiration tests will be performed at the VW and every vapor MP where bacterial degradation of hydrocarbons is indicated by low initial oxygen levels (<2%) and elevated carbon dioxide concentrations in the soil gas. Air will be injected into MPs at the screened intervals containing low levels of oxygen. A 20-hour period of air injection using a 1-cfm air pump will be used to oxygenate local contaminated soils. At the end of the 20-hour air injection period, the air supply will be cut off, and oxygen and carbon dioxide levels will be monitored for the following 48 to 76 hours. The decline in oxygen and increase in carbon dioxide concentrations over time will be used to estimate rates of bacterial degradation of fuel residuals. A helium tracer will also be injected at each MP and monitored for the duration of the respiration test to insure that oxygen loss is not the result of leaking MPs.

3.8 Air Permeability Test

The objective of the air permeability test is to determine the extent of the subsurface that can be oxygenated using one air injection VW. At each site, air will be injected into the VW using the 10-30 scfm test blower unit, and pressure response will be measured at each MP with differential pressure gages to determine the region influenced by the unit. Oxygen will also be monitored in the MPs to ascertain whether oxygen levels in the soil increase as the result of air injection. One air permeability test lasting 4 to 8 hours will be performed.

3.9 Extended Pilot Test Bioventing Systems

Long-term bioventing pilot systems will also be installed at each of the four sites. The blower systems will be chosen based upon the results of the initial respiration and air permeability tests. However, it is anticipated that the extended test blowers will have flow rates in the range of 30 to 50 cfm and will not exceed 2.5 horsepower. The blowers will be housed in small, prefabricated sheds to provide protection from the weather. A licensed electrician subcontracted to ES will perform the connections between the existing breaker box and the blower and starter. The power sources will be the same as those used for the initial pilot tests.

The systems will be in operation for 1 year, and every 6 months ES personnel will conduct *in situ* respiration tests to monitor the long-term performance of these bioventing systems. Weekly system checks will be performed by Hill AFB personnel. If required, major maintenance of the blower units will be performed by ES personnel. Detailed blower system information and maintenance schedules will be included in the operation and maintenance (O&M) manuals provided to the plant. More detailed information regarding the test procedures can be found in the protocol document.

4.0 EXCEPTIONS TO PROTOCOL PROCEDURES

The procedures that will be used to construct the MPs at Site 510.8 and measure the air permeability of the soil and *in situ* respiration rates are described in Sections 4 and 5 of the protocol document. The VWs and MPs installed by Radian Corporation and EA, Engineering, Science, and Technology generally follow the ES protocol procedures. No exceptions to the protocol procedures are anticipated for the field activities.

5.0 BASE SUPPORT REQUIREMENTS

The following Hill AFB support is needed prior to the arrival of the drilling subcontractor and the ES test team:

- Assistance in obtaining drilling and digging permits from Hill AFB. This will include permits for resampling soils at Sites 204.1, 214.1, 228, and 924.
- Power supply with a breaker box at Site 388.
- Provision of any paperwork required to obtain gate passes and security badges for approximately two ES employees, two drillers, and an electrician (if a base electrician is not available). Vehicle passes will be needed for one truck and a drill rig.

During the initial testing, the following base support is needed:

- Twelve square feet of desk space and a telephone in a building located as close to the sites as practical.
- Parking space for one 8x20-foot field trailer located as close to the pilot test areas as practical.
- The use of a facsimile machine for transmitting up to 50 pages of test results.
- A decontamination pad where the driller can clean augers between borings.
- Acceptance of responsibility by the base for drill cuttings from the MP borings at Sites 510.8, 204.1, 214.1, 228, 924, including any drum sampling to determine hazardous waste status.

During the 1-year extended pilot tests, base personnel will be required to perform the following activities:

- Check the blower systems once per week to ensure that they are operating and to record the operating parameters (pressure, vacuum, and temperature). ES will provide a brief training session on this procedure.

- If a blower stops working, notify Mr. John Ratz, Mr. Doug Downey, or Ms. Gail Saxton, ES-Denver (303) 831-8100, or Mr. Jim Williams, Air Force Center for Environmental Excellence (AFCEE) (800) 821-4528, ext. 293.
- Arrange site access for an ES technician to conduct *in situ* respiration tests approximately 6 months and 1 year after the initial pilot test.

6.0 PROJECT SCHEDULE

The following schedule is contingent upon timely approval of this pilot test work plan.

Event	**Date**
Draft Test Work Plan to AFCEE/Hill AFB	May 5, 1993
Notice to Proceed	May 12, 1993
Begin Pilot Test	July 21, 1993
Complete Initial Pilot Test	August 20, 1993
Interim Results Report	October 1, 1993
Respiration Test	January 1994
Final Respiration Test	July 1994

7.0 POINTS OF CONTACT

Mr. Andrew Gemperline
OO-ALC/EMR
7276 Wardleigh Rd.
Hill AFB, UT 84056-5127
(801) 777-6919

Major Ross Miller/Mr. Jim Williams
AFCEE/EST
Brooks Air Force Base, TX 78235-5328
(210) 536-5246

Mr. Doug Downey/Mr. John Ratz
Engineering-Science, Inc.
1700 Broadway, Suite 900
Denver, CO 80290
(303) 831-8100
Fax (303) 831-8208

8.0 REFERENCES

EA Engineering, Science, and Technology, 1992a. *Subsurface Investigation Report Site 388, Hill Air Force Base, Utah.* Lincoln, Nebraska, October.

EA Engineering, Science, and Technology, 1992b. *Corrective Action Plan Site 510.8 (AFLB), Hill Air Force Base, Utah.* Lincoln, Nebraska. November.

EA Engineering, Science, and Technology, Inc. 1991. *Subsurface Investigation Report, Tank 510.8 (Site AFLB)*. Lafayette, California.

Engineering-Science, Inc., 1992. *Project Management Plan AFCEE Bioventing Pilot Tests: Appendix D-Field Sampling Plan.* April. Denver, Colorado.

Engineering-Science, Inc., 1993. *Subsurface Investigation Report, Site 40002, Hill Air Force Base, Utah.* Salt Lake City, Utah. January.

Hinchee, R.E., S.K. Ong, R.N. Miller, D.C. Downey, and R. Frandt, 1992. *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing.* Columbus, Ohio. January.

Radian Corporation, 1993. *Underground Storage Tank Site 1705, Abatement and Initial Site Characterization Report, Subsurface Investigation, Hill Air Force Base, Utah.* Salt Lake City, Utah. January.

APPENDIX A

VENT WELL AND MONITORING POINT COMPLETION DETAILS

SOIL VAPOR EXTRACTION WELL

Date 7-08-92

Geologist Bruce Haley

Job Number 60187.05

Client Hill AFB, EMR

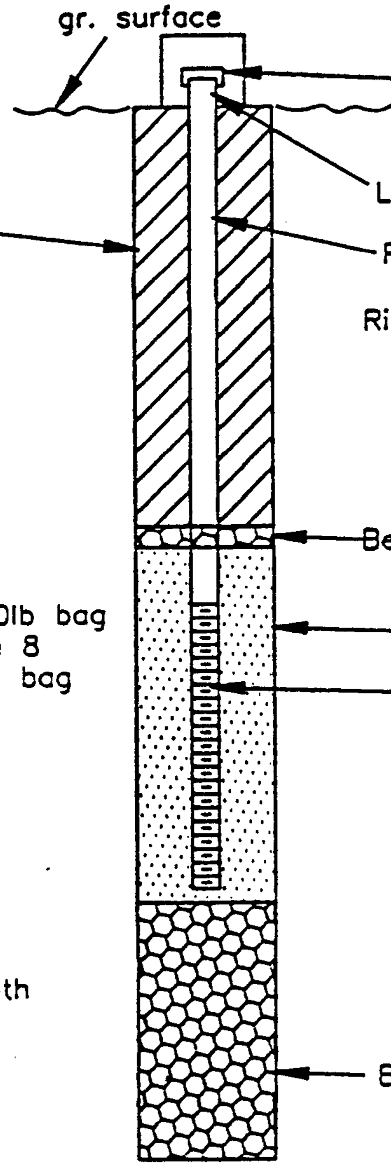
Well Number 388 MW-1/SVE-1

Driller PC Exploration
David Mott

Lic. #

Drilling Method HSA
CME 75

gr. surface



Protective Cover yes or no

Type Steel

Bore hole diameter
8.25 OD
4.50 ID

Length of well stick up 2.5 ft

Sealing Material
Cement/Bentonite

Riser pipe diameter 2" schedule 80

Type Slurry

Riser pipe length from 25 to 2.5
above surface

Proportions
97% 3%

Bentonite Pellets/Slurry
from 22 to 20

Depth from 20 to 3

Pure Wyoming Bentonite 50lb bag
Gramusil Silica Sand Grade 8
- 100lb bag

Filter pack from 77 to 22

Screen diameter 2" schedule 80

Slot size 0.020

Screen set from 75 to 25

Total hole depth 149 backfill
to 77

Note:
All footages equal to depth below ground surface

Bentonite Backfill

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

Figure 2-1

SOIL VAPOR PROBE INSTALLATION

Date 7-13-92

Geologist Bruce Haley Job Number 60187.05

Client Hill AFB, UT

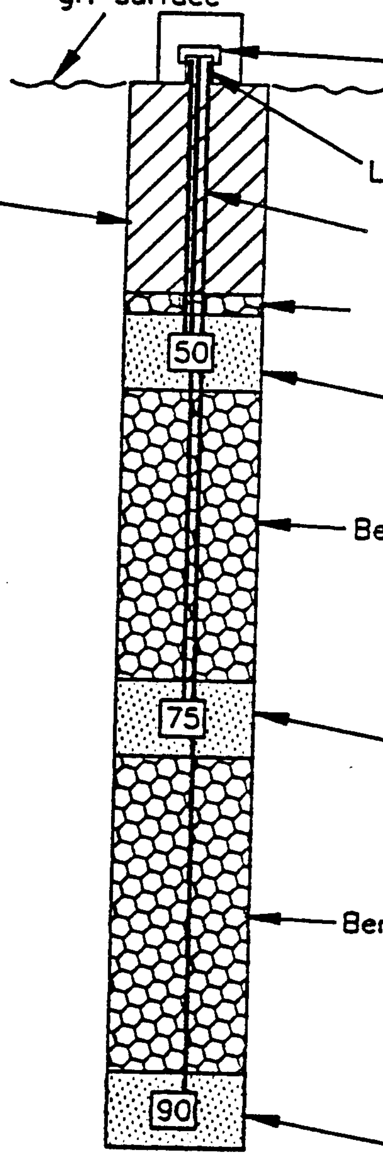
Well Number 388 SB-2

Driller PC Exploration

Lic. # ____

Drilling Method HSA

gr. surface



Protective Cover yes or no

Type Steel

Bore hole diameter 8.25 OD

Length of well stick up 2.5 ft

Sealing Material Cement/Bentonite grout

Tubing diameter 0.25 in

Type ____

2 ft Bentonite Seal

Bentonite from 48 to 46

Proportions 97%/3%

Filter pack from 52 to 48

Depth from 90 to 3

Bentonite Seal

Bentonite from 73 to 52

Filter pack from 77 to 73

Vapor Probes 1 in. ID PVC

Slot size 0.010

Bentonite Seal

Bentonite from 88 to 77

Filter pack from 90 to 88

Total hole depth 90 ft

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

Figure 2-2

SOIL VAPOR PROBE CONSTRUCTION

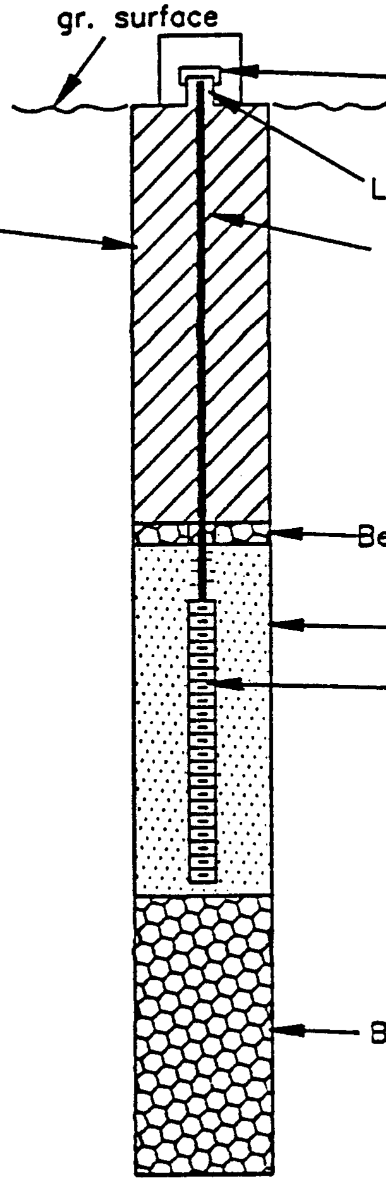
Date 7-13-92   Geologist Bruce Haley   Job Number 60187.05

Client Hill AFB, UT   Well Number 388 SB-5

Driller PC Exploration   Lic. # ______

Drilling Method HSA

gr. surface



Protective Cover yes or no

Type Steel

Bore hole diameter 8.25 OD

Length of well stick up 2.5 ft

Sealing Material Cement/Bentonite grout

Tubing diameter 0.25 in

Type ______

Tubing length from 94 to __ surface

Proportions 97%/3%

Depth from 90 to 3

Bentonite Pellets/Slurry from 92 to 90

Filter pack from 96 to 92

Screen diameter 1 in.

Slot size 0.010

Screen set from 94 to 93.5

Total hole depth 120

Bentonite Backfill

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

Figure 2-3

SOIL VAPOR PROBE CONSTRUCTION

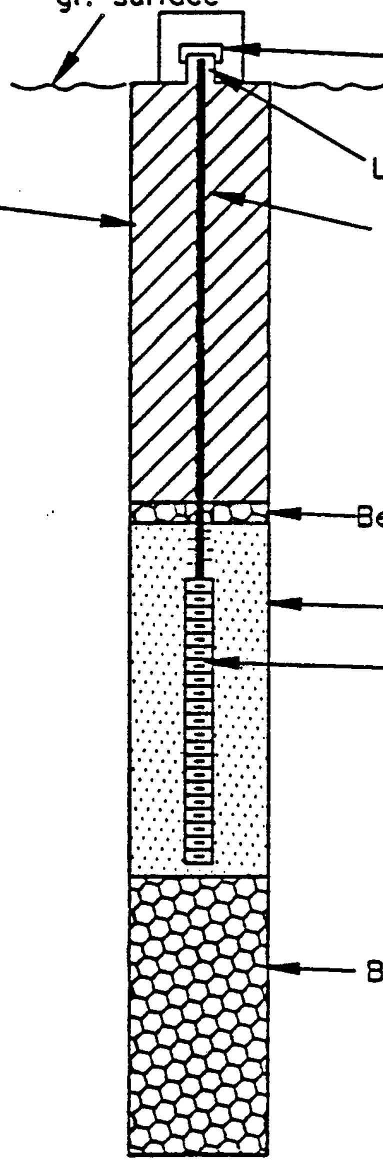
Date 7-14-92 Geologist Bruce Haley Job Number 60187.05

Client Hill AFB, UT Well Number 388 SB-6

Driller PC Exploration Lic. # ______

Drilling Method HSA

gr. surface



Protective Cover yes or no
Type Steel

Bore hole diameter
8.25 OD

Length of well stick up 2.5 ft

Sealing Material
Cement/Bentonite grout

Tubing diameter 0.25 in

Type ______

Tubing length from 94 to ___ surface

Proportions
97%/3%

Depth from 90 to 3

Bentonite Pellets/Slurry
from 92 to 90

Filter pack from 96 to 92

Screen diameter 1 in.

Slot size 0.010

Screen set from 94 to 93.5

Total hole depth 120

Bentonite Backfill

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

Figure 2-4

SOIL VAPOR EXTRACTION WELL

Date 7-14-92 Geologist Bruce Haley Job Number 60187.02

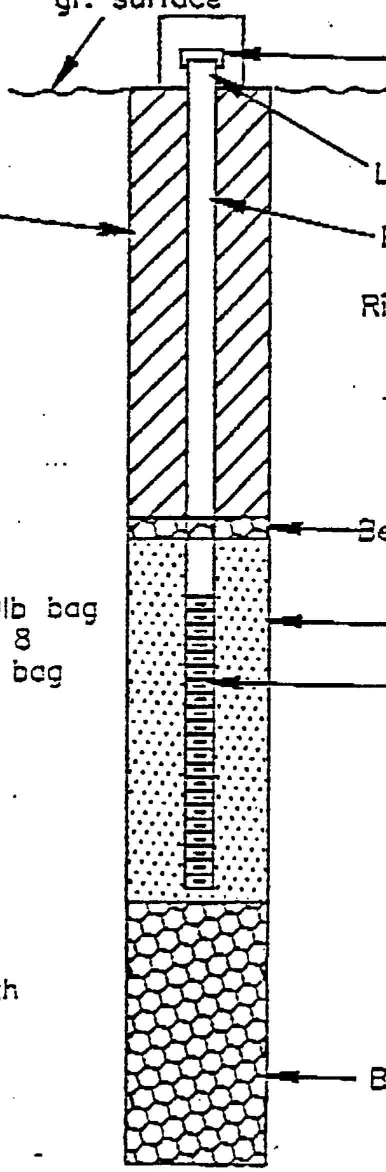
Client Hill AFB, EMR Well Number 510SVE-1

Driller PC Exploration
David Mott

Lic. # ________

Drilling Method HSA
CME 75

gr. surface



Protective Cover yes or no

Type Steel

Bore hole diameter
8.25 OD
4.50 ID

Length of well stick up 2.0 ft

Sealing Material
Cement/Bentonite

Riser pipe diameter 2" schedule 40

Type Slurry

Riser pipe length from 34 to 2.0 above surface

Proportions
97% 3%

Bentonite Pellets/Slurry from 32 to 30

Depth from 30 to 3

Pure Wyoming Bentonite 50lb bag
Gramusii Silica Sand Grade 8
100lb bag

Filter pack from 64 to 32

Screen diameter 2" schedule 40

Slot size 0.020

Screen set from 64 to 34

Total hole depth 74 backfill to 64

Note:
All footages equal to depth below ground surface

Bentonite Backfill

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

Figure 4-3

RADIAN
CORPORATION

Air Injection Well #: T17051VW

Page 1 of 1

LOG OF DRILLING OPERATIONS

PROJECT: HILL AFB SITE 1705   LOCATION: OGDEN, UTAH
TOTAL DEPTH: 23.00   START DATE: 11/11/92   FINISH DATE: 11/12/92
GEOLOGIST: Bill Bender   APPROVED BY: R.G.#:
DRILLING COMPANY: PC Exploration   DRILLER: Mark Clark
DRILLING METHOD: Hollow Stem Auger   EQUIPMENT: Mobile B-61
DRILL BIT TYPE AND SIZE: 8.25" I.D.
BORING LOCATION (ST. ADDRESS OR DESCRIPTION): Adjacent to Building 1705

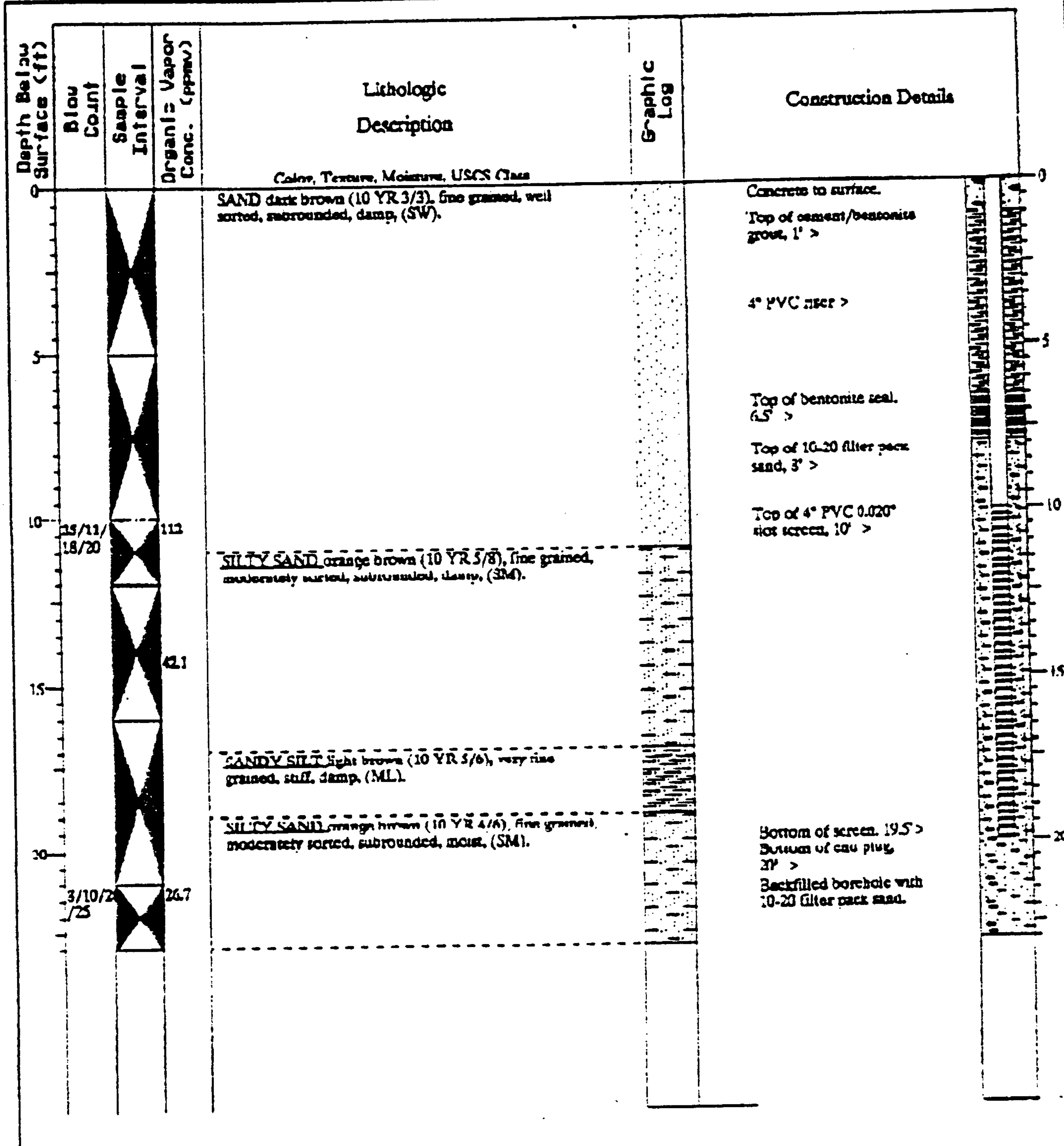


Figure 7-2

RADIAN
CORPORATION

Soil Vapor Probe #: T17052VW

Page 1 of 1

LOG OF DRILLING OPERATIONS

PROJECT: HILL AFB SITE 1705 — LOCATION: OGDEN, UTAH
TOTAL DEPTH: 25.00 — START DATE: 11/12/92 — FINISH DATE: 11/12/92
GEOLOGIST: Bill Bender — APPROVED BY: — R.G.#:
DRILLING COMPANY: PC Exploration — DRILLER: Mark Clark
DRILLING METHOD: Hollow Stem Auger — EQUIPMENT: Mobile B-61
DRILL BIT TYPE AND SIZE: 8.25" I.D.
BORING LOCATION (ST. ADDRESS OR DESCRIPTION): Adjacent to Building 1705

Depth Below Surface (ft)	Blow Count	Organic Vapor Conc. (ppmv)	Lithologic Description (Color, Texture, Moisture, USCS Class)
0			SILTY SAND brown (7.5 YR 3/4), very fine grained, moderately sorted, subangular, damp, (SM).
	5/5/5/7	243	
	4/3/5/7	263	
5	4/6/8/11	72	
			SAND orange brown (10 YR 4/6), fine grained, well sorted, damp, (SW).
	6/5/8/13	95	
10	8/10/13/18	80	
			SILTY SAND light brown (10 YR 5/3), very fine grained, moderately sorted, subangular, loose, damp, (SM).
	16/17/19/26	172	
			SANDY SILT light brown (10 YR 5/3), very fine grained, compact, damp, (ML).
	14/15/16/19	73	
15		92	SAND brown (10 YR 6/4), fine grained, well sorted, subangular, damp, (SW).
	13/17/18/26	91	
	14/16/18/20		SAND brown (10 YR 6/4), very fine grained, well sorted, subangular, damp, (SW).
20	14/15/20/24	75.2	SILTY SAND light brown (10 YR 5/4), very fine grained, compact, damp, (SM).
	13/15/13/21	103	
	15/16/18/20	35	SILTY SAND brown (10 YR 4/2), very fine grained, moist (SM)
25			

Construction Details

Concrete to surface.

Top of cement/bentonite grout, 1' >

0.25" I.D. tygon tubing.

Top of bentonite seal, 8' >

Top of 10-20 filter pack sand, 10' >

Top of vapor probe, 11.5' >

1.5" slotted PVC probe. Bottom of soil vapor probe, 13' >

Back filled borehole with 10-20 filter pack sand >

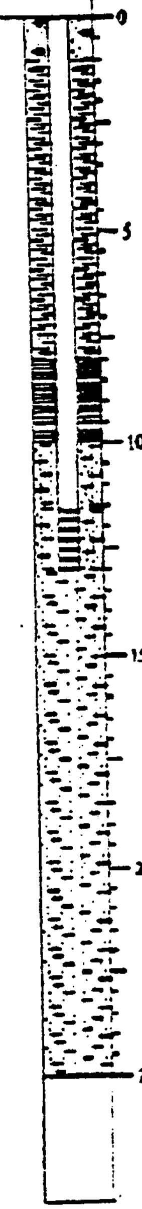


Figure 7-3

RADIAN
CORPORATION

Soil Vapor Probe #: T17053VW

Page 1 of 1

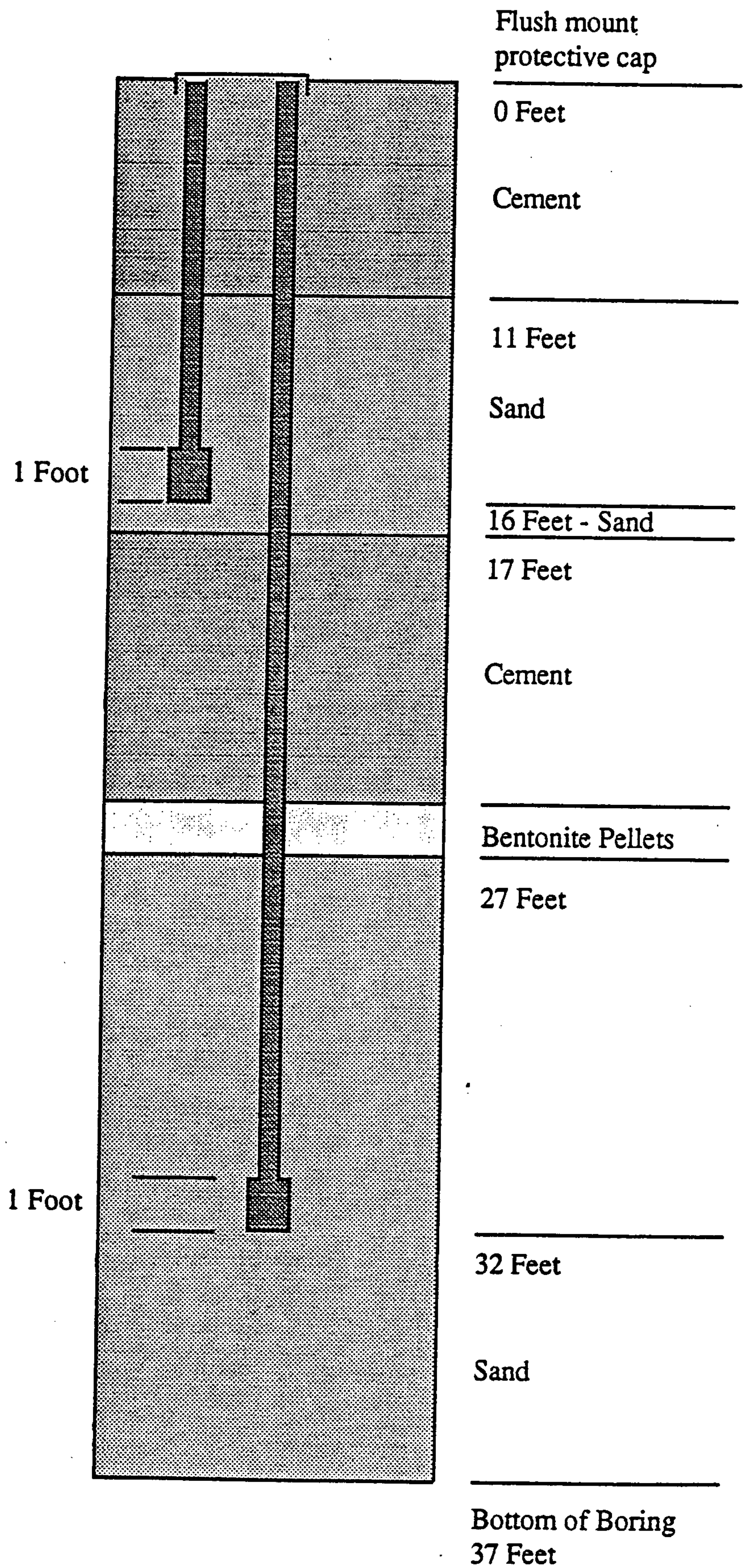
LOG OF DRILLING OPERATIONS

PROJECT HILL AFB SITE 1705 LOCATION OGDEN, UTAH
TOTAL DEPTH 25.00 START DATE 11/12/92 FINISH DATE 11/12/92
GEOLOGIST Bill Bender APPROVED BY R.G.#
DRILLING COMPANY PC Exploration DRILLER Mark Clark
DRILLING METHOD Hollow Stem Auger EQUIPMENT Mobile B-61
DRILL BIT TYPE AND SIZE 8.25" I.D.
BORING LOCATION (ST. ADDRESS OR DESCRIPTION) Adjacent to Building 1705

Depth Below Surface (ft)	Blow Count	Organic Vapor Conc. (ppmv)	Lithologic Description (Color, Texture, Moisture, USCS Class)	Construction Details
0		3.2	SILTY SAND dark brown (10 YR 2/1), fine grained, moderately sorted, damp, (SM).	Concrete to surface. Top of cement/bentonite grout, 1' >
5		5.0	SAND brown orange (10 YR 5/6), fine grained, well sorted, damp, (SW).	0.25" I.D. tygon tubing
10	14/11/ 25/25; 22/25/ 25/30	32; 78	SILTY SAND orange brown (10 YR 6/6), fine grained, moderately sorted, damp, (SM).	Top of bentonite seal, 10' >
	13/23/ 23/25	12.2	SAND light brown (10 YR 6/4), fine grained, well sorted, subangular, damp, (SW).	Top of 10-20 filter pack sand, 12' >
15	13/20/ 22/23	119	SANDY SILT orange brown (10 YR 5/6), very fine grained, damp, (ML).	Top of vapor probe, 13.9' > 1.5' slotted PVC probe > Bottom of soil vapor probe, 15.4' >
	10/18/ 20/30; 11/13/ 21/28	43; 73	SILTY SAND light brown (10 YR 5/4), fine grained, moderately sorted, subrounded, damp, (SM).	
20	7/11/ 14/19; 10/13/ 15/18		SANDY SILT dark brown (10 YR 4/3), very fine grained, wet, (ML)	Back filled borehole with 10-20 filter pack sand >
25				

Figure 7-4

UTTR Refueling Station
Soil Vapor Monitors
Boring SB06 and SB09

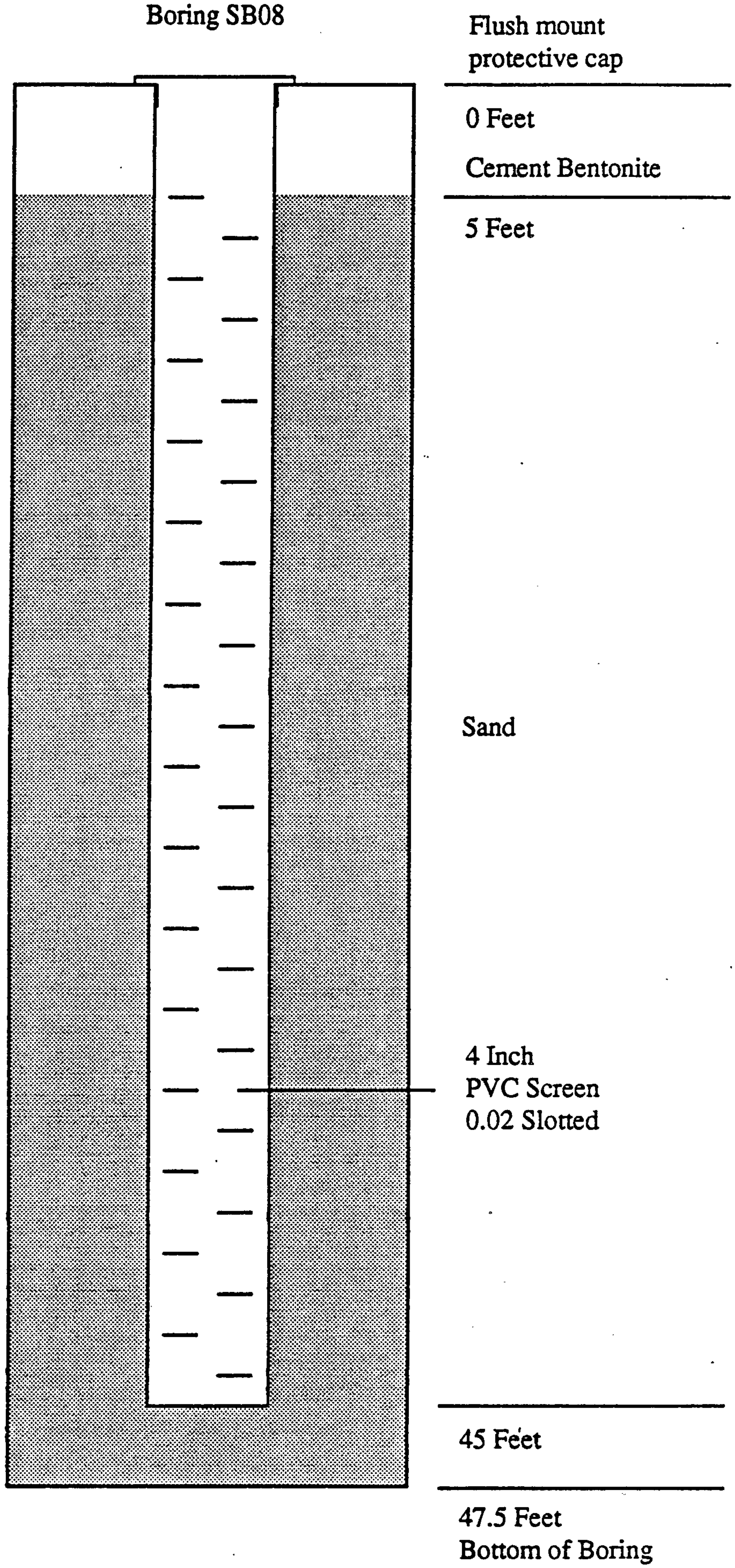


Note: Not to scale

UTTR Refueling Station

Air Injection Well

Boring SB08



Note: Not to scale

PART II
DRAFT INTERIM PILOT TEST RESULTS REPORT FOR FOUR ADDITIONAL BIOVENTING SITES HILL AIR FORCE BASE, UTAH

Prepared for:

Air Force Center for Environmental Excellence
Brooks Air Force Base, Texas

and

Ogden Air Logistics Center/EMR
Hill Air Force Base, Utah

Prepared by:

Engineering-Science, Inc.
1700 Broadway, Suite 900
Denver, Colorado

March 1994

022/722408/1.DOC

CONTENTS

CONTENTS (Continued)

TABLES

CONTENTS (Continued)

FIGURES

PART II

INTERIM PILOT TEST RESULTS REPORT FOR SITES 388, 510.8, 1705, AND 40002 HILL AFB, UTAH

Initial bioventing pilot tests were completed by Engineering-Science, Inc. (ES) at four sites at Hill Air Force Base (AFB), Utah during the period from July 13 through August 16, 1993. The purpose of this Part II report is to describe the results of the initial pilot tests at Sites 388, 510.8, 1705, and 40002, and to make specific recommendations for extended testing to determine the long-term impact of bioventing on site contaminants. Descriptions of the history, geology, and contamination at each of the sites are provided in Part I, the Bioventing Pilot Test Work Plan.

1.0 SITE 388

1.1 Pilot Test Design

This section describes the final design and installation of the bioventing system at Site 388. One vent well (VW-1) and five vapor monitoring points (MPs) were installed at Site 388 by other Air Force contractors prior to ES involvement. In addition, a second VW (VW-2) was installed by Montgomery Watson in coordination with ES after the completion of the initial bioventing pilot testing. ES installed a blower unit and manifolding system that currently injects air into both VWs. Figure 1.1 depicts the locations of the VWs, MPs, manifolding, and blower unit installed at Site 388.

1.1.1 Air Injection Vent Wells

Two air injection VWs were installed by other Air Force contractors following procedures described in the Air Force Center for Environmental Excellence (AFCEE) bioventing protocol document (Hinchee et al., 1992). The locations of the VWs are illustrated in Figure 1.1, and construction details are included in Appendix A.

VW-1 was constructed using 2-inch-diameter, Schedule 80 polyvinyl chloride (PVC) casing, with 50 feet of 0.02-inch-slotted PVC screen installed from 25 to 75 feet below ground surface (bgs). The annular space between the well casing and borehole was filled with number 8 silica sand from 22 to 77 feet bgs. Two feet of bentonite pellets, hydrated in place, were placed above the sand, and cement/bentonite slurry then was placed in the annular space to the existing ground surface (EA Engineering, Science, and Technology 1992a). VW-1 was utilized in the initial bioventing pilot test, and is also being utilized in the extended pilot test.

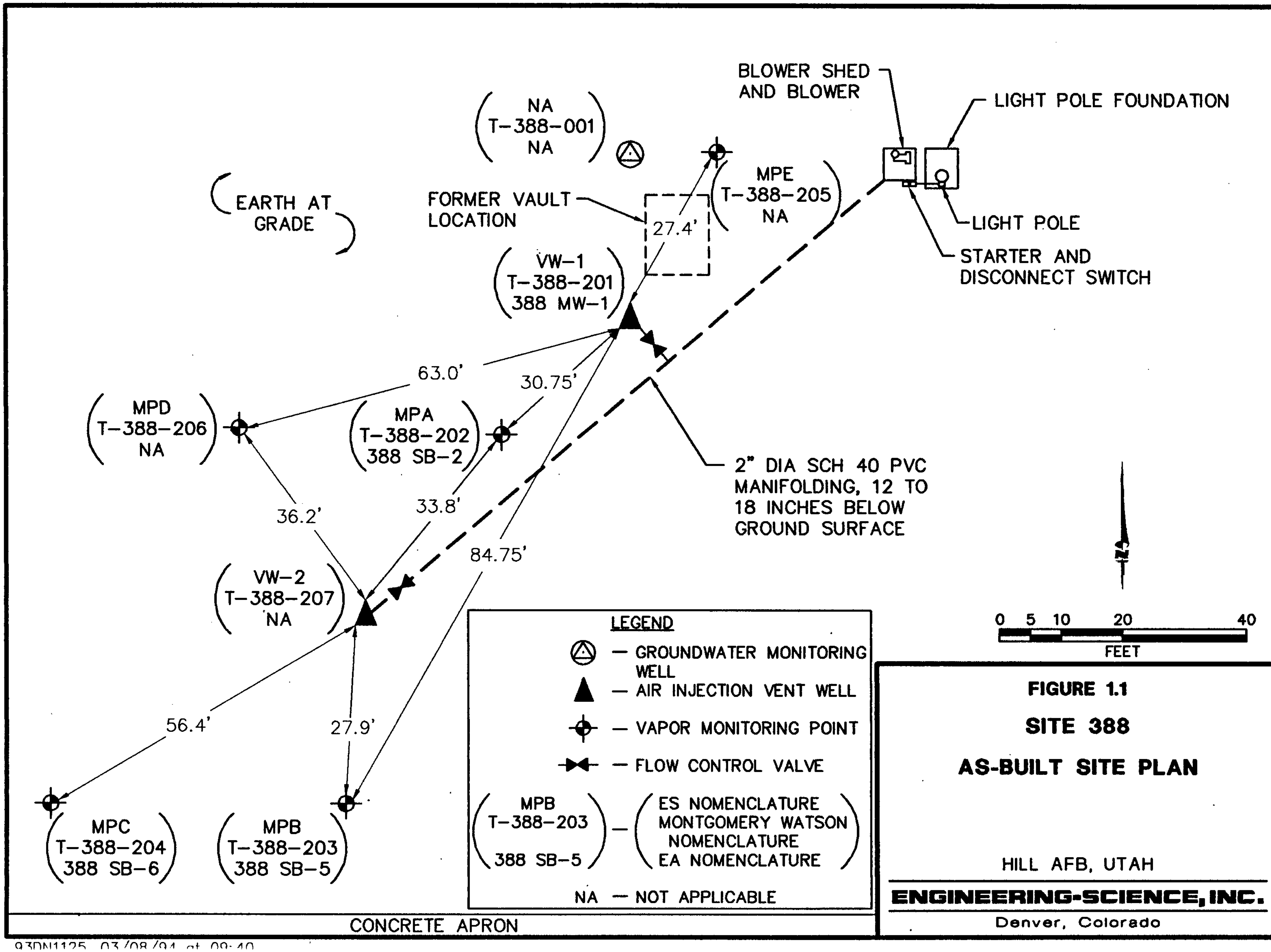


FIGURE 1.1

SITE 388

AS-BUILT SITE PLAN

VW-2 was constructed using 4-inch-diameter, Schedule 40 PVC casing, with 65 feet of 0.02-inch-slotted PVC screen installed from 55 to 120 feet bgs. The annular space between the well casing and borehole was filled with number 8-12 silica sand from 50 to 120 feet bgs. Five feet of bentonite pellets were placed above the sand and hydrated in place, and cement grout was placed in the remainder of the annular space (Montgomery Watson, 1993). VW-2 was constructed after the initial pilot test, and is currently being used for air injection during the extended pilot test.

1.1.2 Monitoring Points

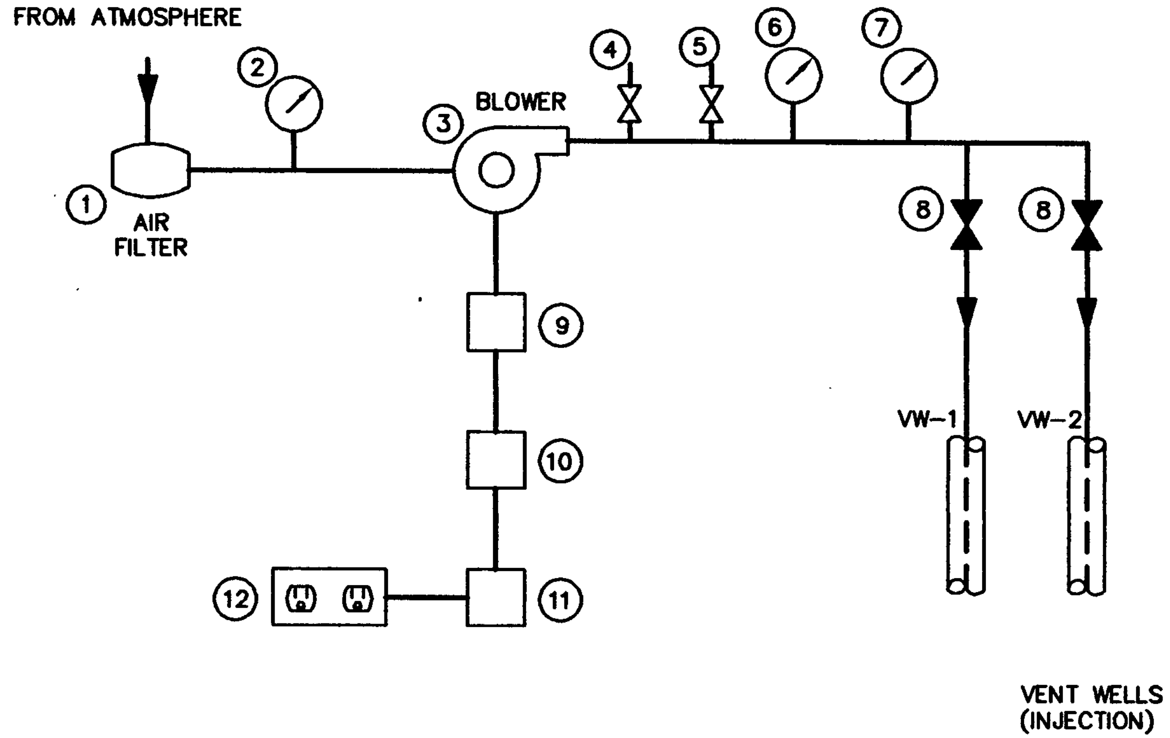
Five MPs were installed at Site 388 at locations shown in Figure 1.1 by other Air Force contractors prior to ES involvement. MPA, MPB, and MPC were installed by EA Engineering, Science and Technology, and MPD and MPE were installed by Montgomery Watson. Construction details for the MPs are included in Appendix A. At MPA, the 6-inch-long MP screens were installed at 50-, 75-, and 90-foot depths bgs. MPB and MPC are screened at 94 feet bgs. Due to faulty MP construction, no soil gas samples or pressure readings could be collected from MPC during the pilot test. Screens at MPD were set at 66 and 100 feet bgs, and screens at MPE were set at three depth intervals: 14, 29, and 39 feet bgs. Each MP screen was constructed using 6-inch sections of 1-inch-diameter PVC well screen with 0.25-inch plastic tubing extending to the ground surface. Each screen was bedded in a sand pack, and bentonite or cement grout seals were placed in the annular space between the sand packs of the screened intervals to prevent soil gas short circuiting. The top of each MP was completed with a 3-foot steel stickup well protector set in concrete.

1.1.3 Blower Unit

A 1-horsepower (HP) Gast® regenerative blower unit was used at Site 388 for the initial pilot test, and a 2.5-HP Gast® regenerative blower was installed at the site for the extended pilot test. The initial pilot test blower was energized by 110-volt, single-phase, 30-amp line power from a receptacle installed on a light pole at the site (Figure 1.1). The extended pilot test blower is energized by 240-volt, single-phase, 30-amp line power, and is housed in a weatherproof enclosure. The 2.5-HP extended pilot test blower is currently injecting air at approximately 140 standard cubic feet per minute (scfm) into VW-1 and VW-2. The configuration, instrumentation, and specifications for the initial pilot test and extended pilot test units are shown on Figure 3.3 of the Work Plan (Part I) and Figure 1.2, respectively. After blower installation and startup, ES engineers provided an operation and maintenance (O&M) manual to Hill AFB personnel. A copy of the manual is provided in Appendix B.

1.2 Soil and Soil Gas Sampling Results

Based on a site investigation by another Air Force contractor, hydrocarbon contamination at Site 388 appears to have migrated to a depth greater than 100 feet bgs, and laterally at least 130 feet to the south-southwest of the former 2,300-gallon underground concrete vault (Figure 1.1). Since the removal of the vault in December 1987, a number of boreholes have been placed in the vicinity of the former vault to determine the extent of contamination (EA Engineering, Science, and Technology, 1992a). The full areal extent of contamination has not yet been defined, and an ongoing site investigation is currently being conducted by Montgomery Watson at



LEGEND

1. INLET AIR FILTER – SOLBERG® F-30P-150
2. VACUUM GAUGE (IN. H_2O)
3. 2 1/2-HP BLOWER – GAST® R5125Q-50
4. MANUAL PRESSURE RELIEF (BLEED) VALVE 1 1/2" GATE
5. AUTOMATIC PRESSURE RELIEF VALVE
6. TEMPERATURE GAUGE (°F)
7. PRESSURE GAUGE (IN. H_2O)
8. FLOW CONTROL VALVE – 2" BALL
9. STARTER – FURNAS® 14CSE33DA NEMA3
10. FUSED DISCONNECT SWITCH-240V/SINGLE PHASE/30 AMP
11. BREAKER BOX-2-20 AMP BREAKER SWITCHES
12. RECEPTACLE-110V

FIGURE 1.2
SITE 388

AS-BUILT
EXTENDED PILOT TEST BLOWER SYSTEM FOR AIR INJECTION

HILL AFB, UTAH

ENGINEERING-SCIENCE, INC.
Denver, Colorado

93DN1116, 02/18/94 at 14:00

Site 388. The soils in the contaminated interval at Site 388 are predominantly fine- to medium-grained sand with some silty sand lenses. Geologic boring logs are included in Appendix A. Results of laboratory analyses of soil samples collected by EA are summarized in Table 1.1. Total recoverable petroleum hydrocarbon (TRPH) detections in contaminated soil ranged from 551 to 14,500 milligrams per kilogram (mg/kg).

Laboratory soil gas samples were collected by ES from VW-1, MPA-75, and MPB-94 prior to initiation of the pilot test. Soil gas samples were collected in 3-liter Tedlar® bags and vacuum chambers. After the samples were collected into Tedlar® bags, they were transferred to 1-liter SUMMA® canisters and shipped to the laboratory. Soil gas samples were shipped via Federal Express® to Air Toxics, Inc. in Folsom, California, for total volatile hydrocarbon (TVH) and benzene, toluene, ethylbenzene, and xylene (BTEX) analysis by US Environmental Protection Agency (EPA) Method TO-3. The TVH analyses were referenced to JP-4 jet fuel. The results of these analyses are provided in Table 1.1.

1.3 Exceptions To Test Protocol

Procedures described in the protocol document (Hinchee et al., 1992) were used to complete the pilot test at Site 388, with the following exceptions. Initial soil sampling performed by other Air Force contractors deviated from the protocol. TRPH samples were analyzed by a modified EPA Method 8015, rather than by Method 418.1, which is specified in the protocol. Soil samples collected during the site investigation were not analyzed for the inorganic parameters specified in the protocol. These analyses will be performed during the 12-month sampling event. No thermocouples were installed at Site 388. Also, due to the widespread extent of contamination at the site, no background points were installed at Site 388. Background conditions at Hill AFB have already been established during prior research efforts (Hinchee and Miller, 1991). The extended pilot testing system currently injects air into two VWs, whereas one VW normally is used in the extended pilot tests.

1.4 Test Results

1.4.1 Initial Soil Gas Chemistry

Prior to initiating air injection, all MPs and VW-1 were purged, and initial oxygen, carbon dioxide, and TVH concentrations were determined using portable gas analyzers, as described in the technical protocol document (Hinchee et al., 1992). Table 1.2 summarizes the initial soil gas chemistry at Site 388. The results strongly indicate that biological fuel degradation has depleted the oxygen supply in the vadose zone soils. VW-1 and each MP screen were under anaerobic conditions. Carbon dioxide was present at elevated concentrations, ranging from 9.6 to 12.5 percent, in all initial soil gas samples collected at Site 388. Although no background point has been installed at Site 388, uncontaminated soils typically contain oxygen at concentrations ranging from 15 to 20 percent, and carbon dioxide levels ranging from 0.1 to 3 percent.

1.4.2 Soil Gas Permeability

A soil gas permeability test was conducted at Site 388 according to protocol procedures. Air was injected into VW-1 at a rate of approximately 73 scfm and an average pressure of approximately 7 inches of water. The pressure response at each

TABLE 1.1
SITE 388
SOIL AND SOIL GAS ANALYTICAL RESULTS
HILL AFB, UTAH

Analyte (Units)[a/]	Sample Location-Depth (feet below ground surface)		
Soil Hydrocarbons[b/]	VW-1-65	MPA-59	MPB-104
TRPH (mg/kg)	14,500	551	7,330
Benzene (mg/kg)	5.19	ND (0.25) [c/]	ND (0.5)
Toluene (mg/kg)	111	2.5	15.3
Ethylbenzene (mg/kg)	55.3	3.34	15.4
Xylenes (mg/kg)	559	39.28	153.8
Soil Gas Hydrocarbons	VW-1-25-75	MPA-75	MPB-94
TVH (ppmv) [d/]	27,000	19,000	33,000
Benzene (ppmv)	210	15	300
Toluene (ppmv)	270	12	250
Ethylbenzene (ppmv)	15	3.3	8.5
Xylenes (ppmv)	160	15	66
Soil Physical Parameters[b/]	VW-1-94	MPA-59	
Moisture (% wt.)	4.3 [e/]	25.3	
Gravel (%)	0	NS [f/]	
Sand (%)	68	NS	
Silt and Clay (%)	32	NS	

a/ TRPH=total recoverable petroleum hydrocarbons; mg/kg=milligrams per kilogram; TVH=total volatile hydrocarbons; ppmv=parts per million, volume per volume.
b/ EA Engineering, Science, and Technology, 1992a.
c/ ND=not detected at method detection limit (in parentheses).
d/ TVH referenced to jet fuel (molecular weight=156).
e/ Moisture data from 65 feet bgs.
f/ NS=not sampled.

TABLE 1.2
SITE 388
INITIAL SOIL GAS CHEMISTRY
HILL AFB, UTAH

MP	Depth (feet bgs)	O_2 (%)	CO_2 (%)	Field TVH (ppmv)	Lab TVH[a/] (ppmv)
VW-1	25-75	0.0	10.3	13,200	27,000
A	50	0.0	10.8	330	NS [b/]
A	75	0.0	12.2	9,600	19,000
A	90	0.0	11.9	4,000	NS
B	94	0.0	10.6	16,000	33,000
D	66	0.0	9.6	4,400	NS
D	100	0.0	10.3	8,000	NS
E	14	0.0	12.5	5,600	NS
E	29	0.0	11.3	4,300	NS
E	39	0.0	11.7	6,600	NS

a/ Lab TVH referenced to jet fuel (molecular weight=156).
b/ NS = not sampled.

MP is recorded in Table 1.3. Due to the slow pressure response and relatively long time to achieve steady-state pressures, the HyperVentilate® model was used to calculate air permeabilities (Hinchee et al., 1992). Calculated air permeability values ranged from 52 to 287 darcys, indicating that soil in fuel-contaminated zones at Site 388 is highly permeable to air flow and should be easily oxygenated. A radius of pressure influence of 85 feet was achieved in deeper soils, as demonstrated by the pressure response observed at MPB. Results at MPD demonstrated that a radius of pressure influence of at least 63 feet could be achieved at all monitored depths.

1.4.3 Oxygen Influence

The depth and radius of oxygen influence in the subsurface resulting from air injection into the central VW during pilot testing is the primary design parameter for full-scale bioventing systems. Optimization of full-scale and multiple VW systems requires pilot testing to determine the volume of soil that can be oxygenated at a given flow rate and VW screen configuration.

Table 1.4 describes the changes in soil gas oxygen levels that occurred during the 19-hour soil gas permeability test, during which air was injected into VW-1 only. Changes in oxygen levels that occurred after 48.5 hours of air injection into both VW-1 and VW-2 with the extended pilot testing system also are included in Table 1.4. Using the extended pilot testing system, significant increases in the oxygen concentration were measured at each MP interval with the exception of MPA-75. It is possible that MPA-75 has been set in a layer of soil with lower permeability relative to the zones of soil above and beneath it, causing injected oxygen-rich air to bypass the layer. Because pressure influence was observed at MPA-75 during the air permeability test, it is expected that this sampling point will be oxygenated during the extended pilot test. The observed radius of oxygen influence during the operation of the extended pilot testing system was 36.2 feet, the distance between VW-2 and MPD (Figure 1.1). It appears that the radius of oxygen influence for the long-term bioventing system on this site will exceed 65 feet at all depths, based on observed pressure influence. It is not yet known if the entire contaminated region is being oxygenated by the extended pilot testing system. Future monitoring at this site will better define the treatment radius.

1.4.4 *In Situ* Respiration Rates

In situ respiration testing was performed at Site 388 according to protocol document procedures. Air admixed with approximately 4-percent helium, an inert tracer gas, was injected into VW-1 and MP screened intervals MPA-75, MPD-100, and MPE-39 for a 22-hour period at a rate of approximately 1 scfm per screened interval to deliver oxygen to fuel-contaminated soils. At the end of the 22-hour period, air injection ceased and changes in soil gas composition were monitored over time. Oxygen, TVH, carbon dioxide, and helium were measured over a period of 97 hours following the air injection period. The observed rates of oxygen utilization were then used to estimate the aerobic fuel biodegradation rates at Site 388. The results of *in situ* respiration testing are presented in Figures 1.3 through 1.6. Table 1.5 provides a summary of the observed oxygen utilization rates.

Because helium is a conservative, inert gas, the change in helium concentrations over time can be useful in determining if oxygen diffusion is responsible for a portion

TABLE 1.3

SITE 388

PRESSURE RESPONSE AT MONITORING POINTS DURING THE AIR PERMEABILITY TEST

HILL AFB, UTAH

	Pressure Response In MP (inches of water)								
Depth	MPA			MPB	MPD		MPE		
(feet bgs)	50	75	90	94	66	100	14	29	39
Elapsed Time (min.)									
1.0	0.3	0.3	0.3	0.0	0.0	0.0	--	--	--
2.0	0.5	--[a/]	0.2	0.0	0.04	0.0	0.2	0.34	0.4
3.0	--	0.5	0.2	0.0	0.08	0.0	0.24	0.4	0.44
4.0	0.55	--	--	0.0	0.1	0.0	--	--	--
5.0	0.6	0.7	--	0.0	0.12	0.0	--	--	--
6.0	0.6	0.75	0.2	0.0	0.15	0.0	0.3	0.54	0.6
7.0	0.6	--	0.2	0.0	0.18	0.0	0.4	0.55	0.72
8.0	0.6	0.8	0.2	0.0	0.2	0.0	0.4	0.57	0.73
9.0	--	--	--	0.0	0.22	0.0	0.4	0.68	0.78
10	0.75	0.9	0.2	0.05	0.26	0.05	0.42	0.71	0.8
30	0.93	1.2	0.35	0.20	0.50	0.12	0.52	0.85	0.98
60	1.02	1.38	0.52	0.35	0.73	0.33	0.58	0.96	1.09
90	1.1	1.47	0.65	0.58	0.92	0.5	0.62	1.0	1.12
125	1.1	1.5	0.68	0.62	0.95	0.58	0.6	1.0	1.12
180	1.15	1.6	0.80	0.75	1.22	0.59	0.6	1.0	1.15

[a/] -- denotes no reading taken at this time.

A7-4-41

TABLE 1.4
SITE 388
INFLUENCE OF AIR INJECTION AT VENT WELL ON MONITORING POINT OXYGEN LEVELS
HILL AFB, UTAH

MP	Distance From VW-1 (ft)	Depth (feet bgs)	Initial O_2(%)	Final O_2(%) Permeability Test[a/]	Final O_2(%) Long-Term System[b/]
A	30.75	50	0.0	0.0	17.7
A	30.75	75	0.0	0.0	0.0
A	30.75	90	0.0	13.9	19.7
B	84.75	94	0.0	0.0	13.2
D	62.6	66	0.0	0.0	19.7
D	62.6	100	0.0	0.0	11.2
E	27.4	14	0.0	14.6	17.8
E	27.4	29	0.0	11.7	17.7
E	27.4	39	0.0	18.3	18.7

a/ Readings taken at end of 19-hour permeability test. Air was injected into VW-1 only.

b/ Readings taken after approximately 48.5 hours of air injection using the extended pilot test system. Air was injected into both VW-1 and VW-2.

Figure 1.3
Respiration Test
Oxygen and Helium Concentrations
Site 388, VW-1
Hill AFB, Utah

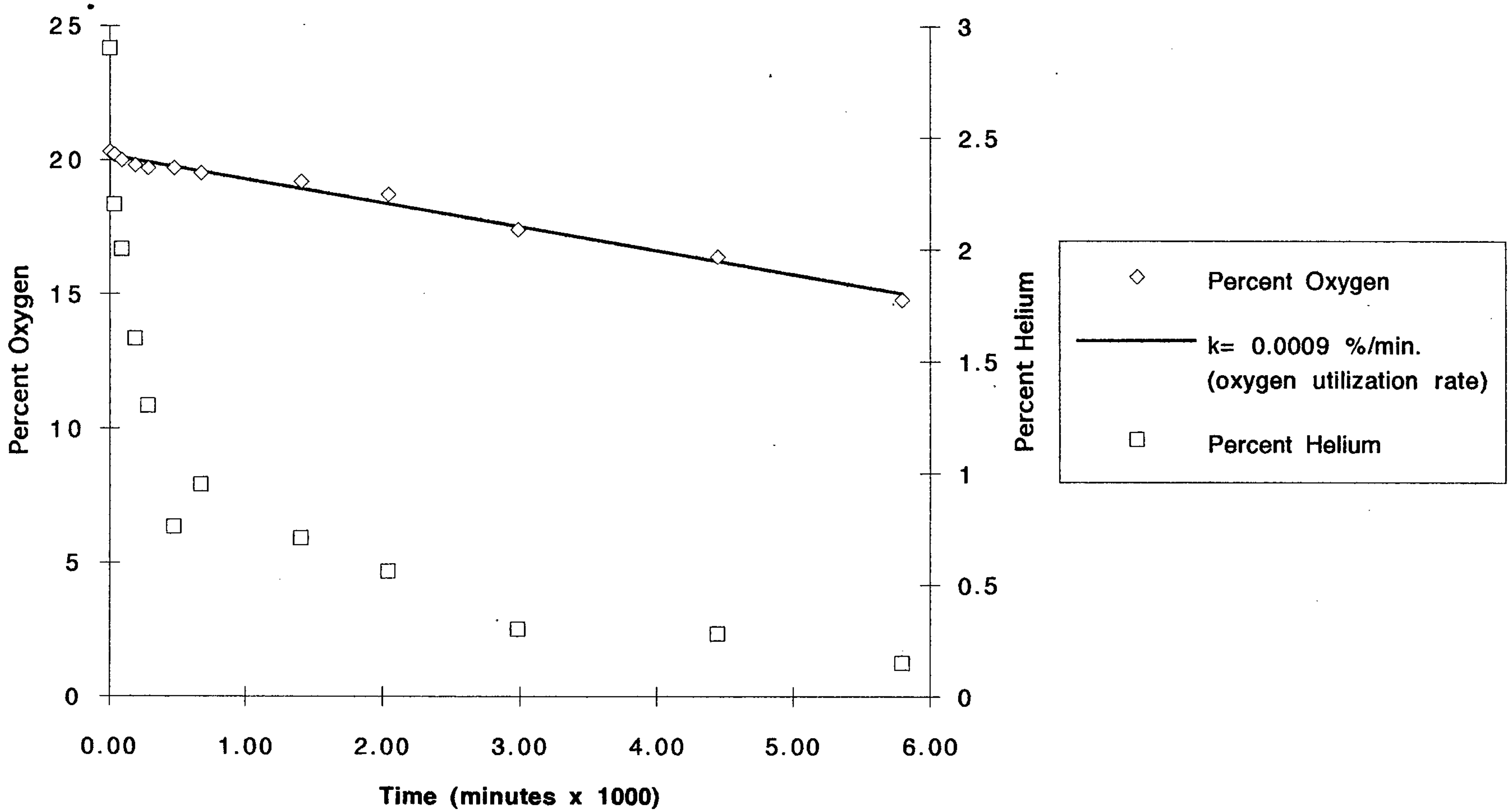


Figure 1.4
Respiration Test
Oxygen and Helium Concentrations
Site 388, MPA-75
Hill AFB, Utah

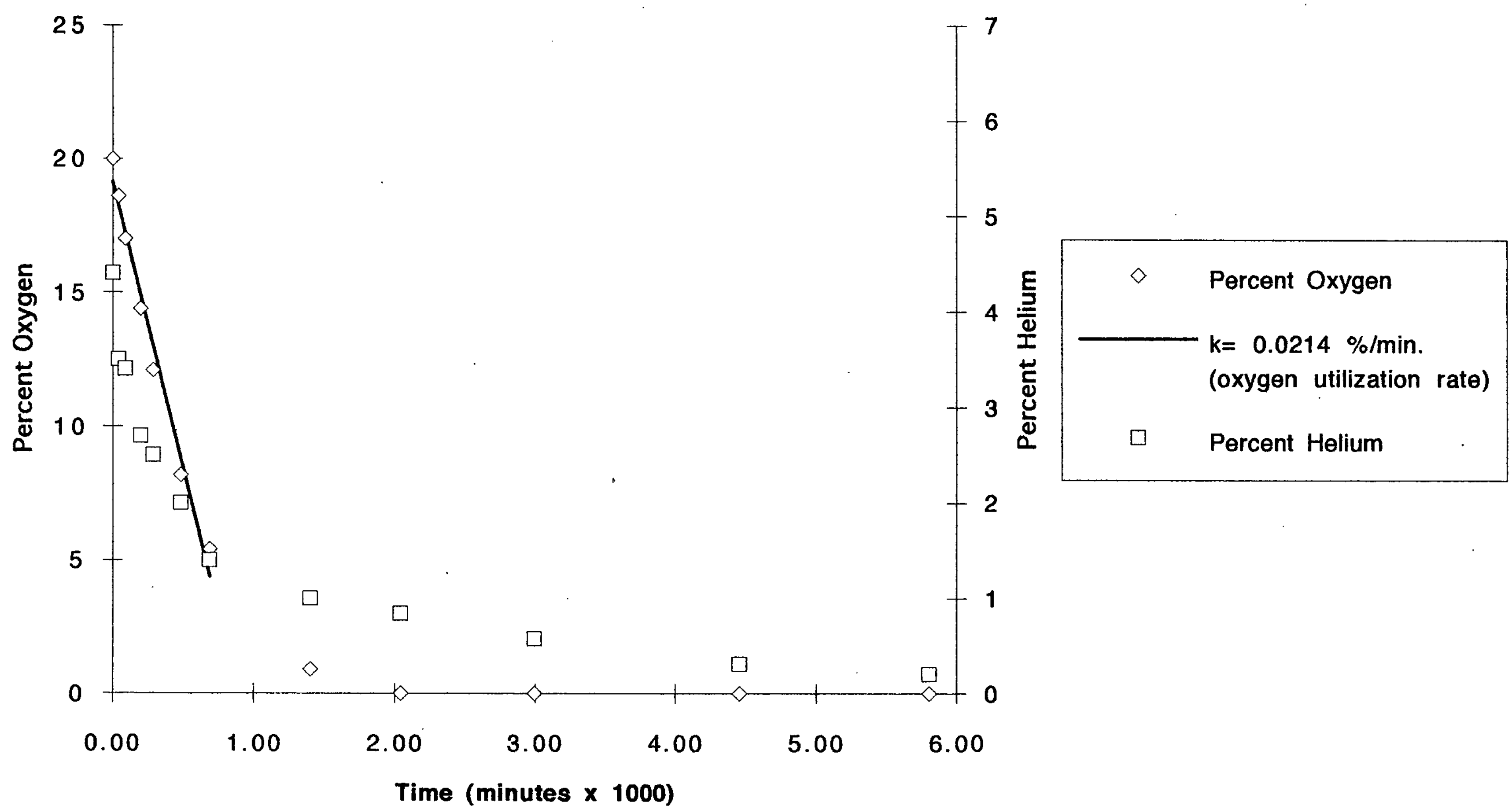


Figure 1.5
Respiration Test
Oxygen and Helium Concentrations
Site 388, MPD-100
Hill AFB, Utah

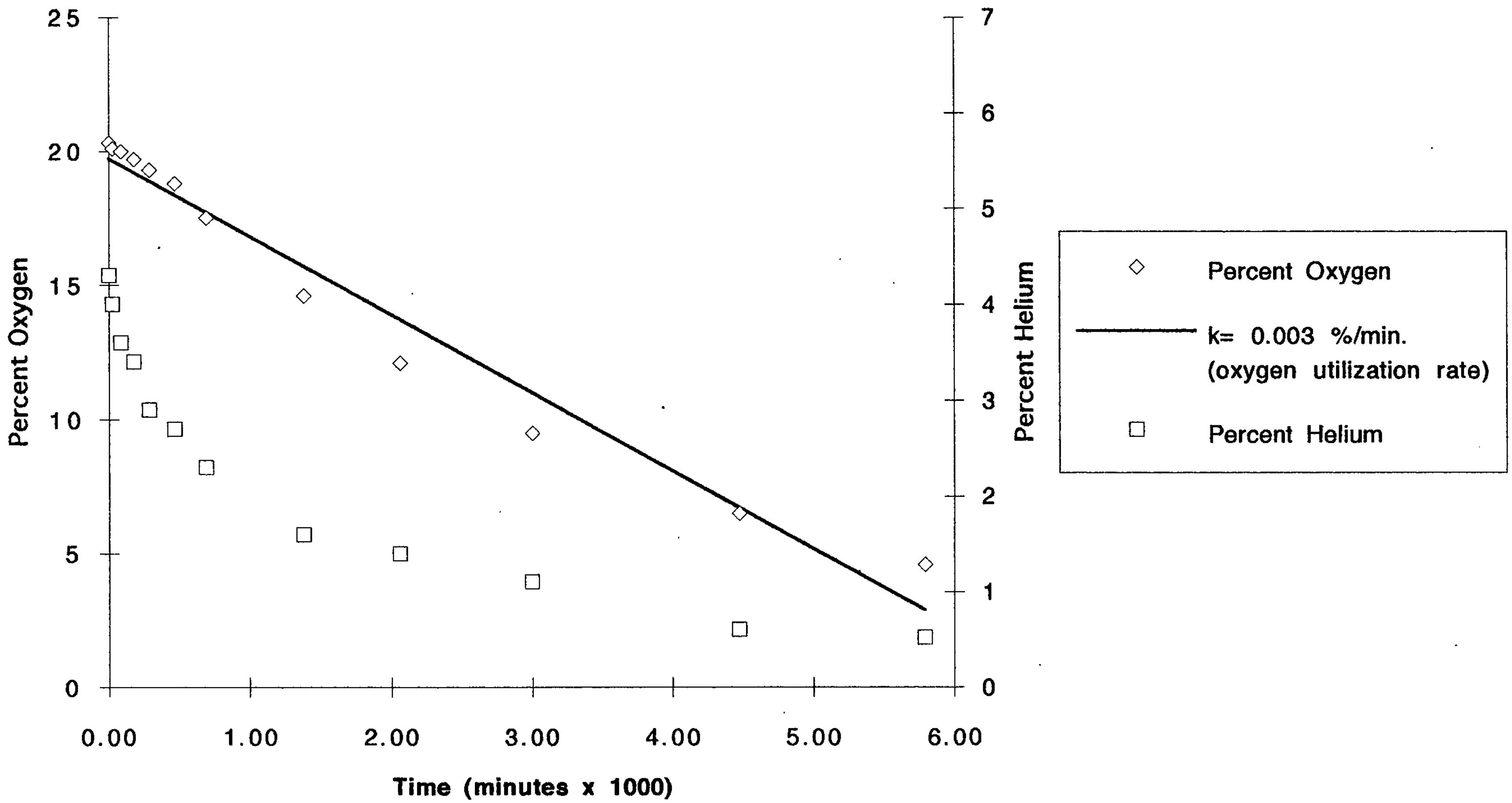


Figure 1.6
Respiration Test
Oxygen and Helium Concentrations
Site 388, MPE-39
Hill AFB, Utah

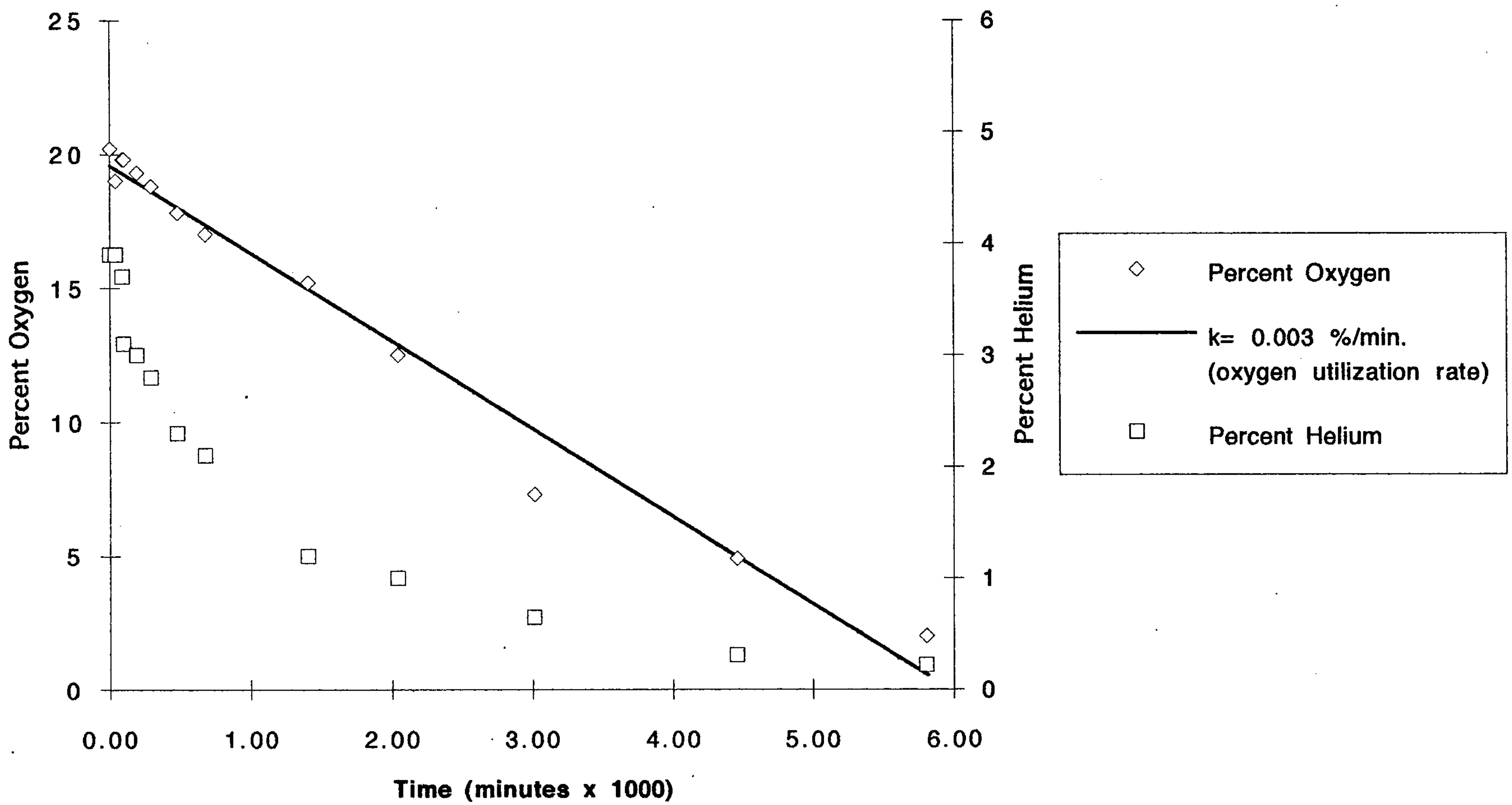


TABLE 1.5
SITE 388
OXYGEN UTILIZATION RATES
HILL AFB, UTAH

MP	O_2 Loss[a/] (%)	Test[b/] Duration (min)	O_2 Utilization[c/] Rate (%/min)
VW-1	5.5	5800	0.0009
MPA-75	20.0	2040	0.0214
MPD-100	15.7	5790	0.003
MPE-39	18.2	5810	0.003

a/ Actual measured oxygen loss.
b/ Elasped time from beginning of test to time when minimum oxygen concentration was measured.
c/ Values based on linear regression (Figures 1.3 through 1.6).

of the oxygen lost from each MP, or if leakage is occurring due to improper MP construction. Figures 1.3 through 1.6 compare oxygen utilization and helium retention. Helium was lost at rapid rates over the first 1,000 minutes of the *in situ* respiration test. However, the rate of helium loss was lower than the rate of oxygen loss for the remainder of the test at all points except the VW, where the rates of helium and oxygen loss were approximately equal. Because the rate of helium loss was significantly less than the rate of oxygen loss at three out of the four testing points, and because helium will diffuse approximately three times faster than oxygen, the measured oxygen loss can be primarily attributed to bacterial respiration rather than diffusion.

At Site 388, an estimated 2,500 mg of fuel per kg of soil can be degraded each year. This value is the average of the fuel consumption rates calculated for every point at which a respiration test was conducted. The MP-specific fuel consumption rates were calculated using observed oxygen utilization rates, estimated air-filled soil porosities, and a conservative ratio of 3.5 mg of oxygen consumed for every 1 mg of fuel biodegraded. Oxygen loss was linear and occurred at rates that ranged from 0.0009 to 0.0214 percent per minute. The air-filled soil porosities calculated for each sampling point ranged from 0.117 to 0.194 liter of air per kg of soil.

1.5 Recommendations

Initial bioventing tests at Site 388 indicate that oxygen has been depleted in fuel-contaminated soils, and that air injection is an effective method of stimulating aerobic fuel biodegradation. AFCEE has recommended that air injection continue on this site to determine the long-term radius of oxygen influence and the effect of time, available nutrients, and changing temperatures on fuel biodegradation rates.

A 2.5-HP regenerative blower has been installed at the site (Figure 1.1) for continuous air injection into VW-1 and VW-2. In March 1994, ES will return to the site to sample and analyze the soil gas and conduct a repeat respiration test. In August 1994, a final respiration test will be conducted, and soil and soil gas samples will be collected from the site to determine the degree of remediation achieved during the first year of *in situ* treatment.

Based on the results of the first year of pilot-scale bioventing, AFCEE will recommend one of three options:

1. Upgrade and continue operation of the bioventing system for full-scale remediation of the site.
2. If final soil sampling indicates significant contaminant removal has occurred, AFCEE may recommend additional sampling to confirm that cleanup criteria have been achieved.
3. If significant difficulties or poor results are encountered during bioventing at this site, AFCEE could recommend the removal of the blower system and proper abandonment of the VWs and MPs.

2.0 SITE 510.8

2.1 Pilot Test Design

This section describes the final design and installation of the bioventing system at Site 510.8. One VW and one groundwater monitoring well were installed at the site by another Air Force contractor in July 1992, prior to ES involvement. In addition, three MPs and a blower unit were installed by ES in August 1993, during initial bioventing pilot testing. Figure 2.1 depicts the locations of the VW, MPs, groundwater monitoring well, and blower unit installed at Site 510.8. Figure 2.2 is a geologic cross-section that illustrates the geology and extent of contamination at the site.

2.1.1 Air Injection Vent Well

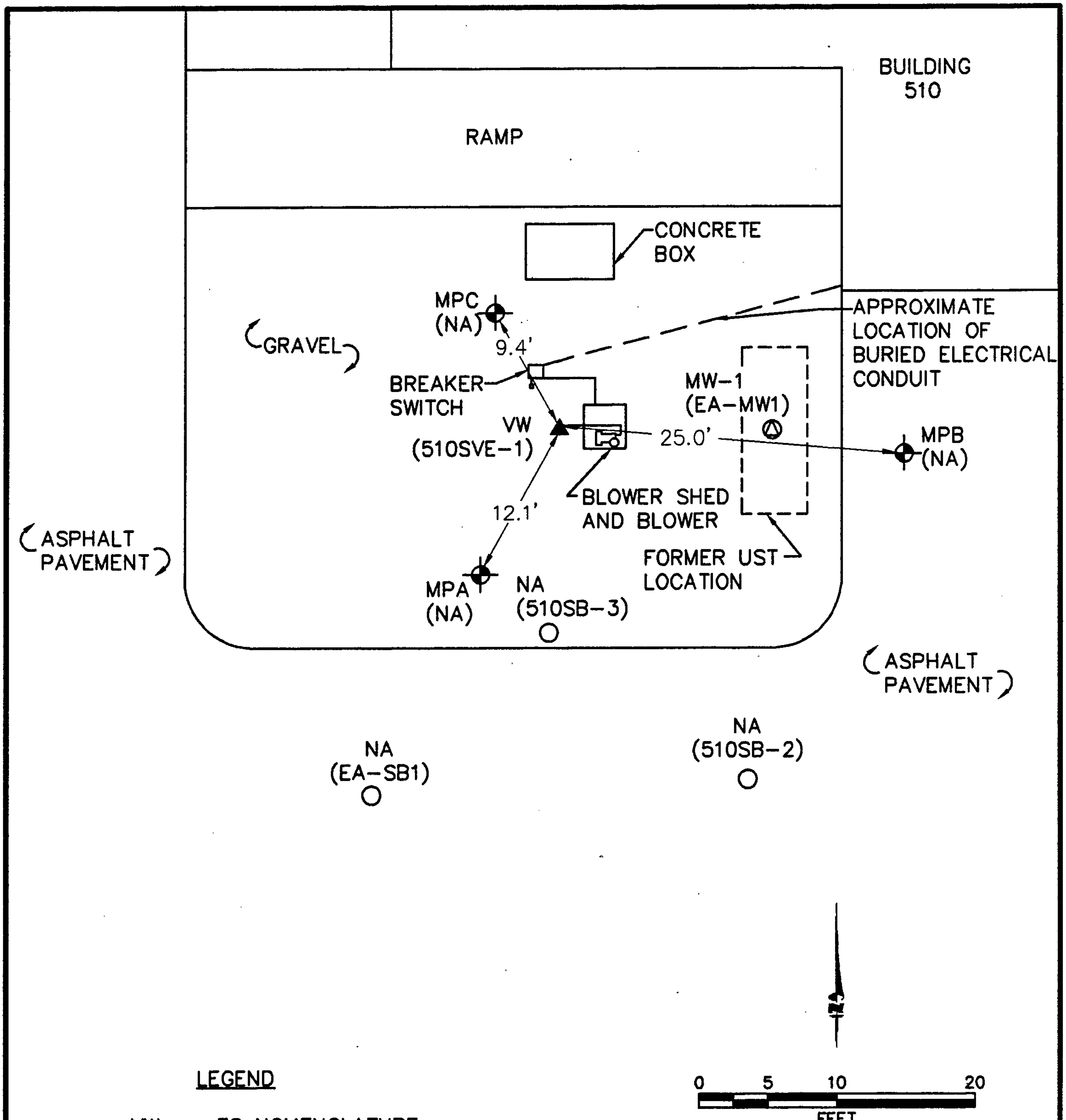
The air injection VW was installed by another Air Force contractor following procedures described in the AFCEE bioventing protocol document (Hinchee et al., 1992). The location of the VW is illustrated in Figure 2.1, and construction details are included in Appendix A. The VW was constructed using 2-inch-diameter, Schedule 40 PVC casing, with 30 feet of 0.020-inch-slotted PVC screen installed from 34 to 64 feet bgs. The annular space between the well casing and borehole was filled with number 8 silica sand from 32 to 64 feet bgs. Two feet of bentonite pellets (hydrated in place) were placed above the sand and overlaid with 30 feet of cement/bentonite grout to the existing ground surface. The top of the well was then completed using a 2-foot steel stickup well protector (EA Engineering, Science and Technology, 1992b).

2.1.2 Monitoring Points

Installation of the three MPs at Site 510.8 began on August 3, 1993, and was completed on August 9, 1993. Drilling services were provided by PC Exploration of Centerville, Utah. MP installation was directed by Mr. John Ratz, the ES site manager. Construction details for MPB are illustrated in Figure 2.3. MP screens at MPB were installed at 20-, 35- and 50-foot depths bgs. The construction details for MPA and MPC are similar to those of MPB, with the depth of the middle screen being the only notable difference. MP screens at MPA and MPC were installed at 20-, 40-, and 50-foot depths bgs. Each MP monitoring interval was constructed using a 6-inch section of 1-inch-diameter Schedule 80 PVC well screen and 0.25-inch Schedule 80 PVC riser pipe extending to the ground surface. At the top of each riser, a ball valve and a 3/16-inch hosebarb were installed. The top of each MP was completed with a flush-mounted metal well protector set in concrete. Thermocouples were installed at the 20- and 50-foot depths at MPA to measure soil temperature variations. The existing groundwater monitoring well MW-1 was also used as a vapor MP during the initial pilot testing.

2.1.3 Blower Unit

A 1-HP Gast® regenerative blower unit was installed at Site 510.8 to inject air into the VW for both the initial and extended pilot tests. The extended pilot test blower is energized by 240-volt, single-phase, 20-amp line power from a breaker box inside Building 510, and is housed in a weatherproof enclosure. The blower system is currently injecting air at a flow rate of approximately 30 scfm for the extended pilot test. The configuration, instrumentation, and specifications for the extended pilot test



LEGEND

VW (510SVE-1) — ES NOMENCLATURE (EA NOMENCLATURE)

— VAPOR MONITORING WELL

— AIR INJECTION VENT WELL

— PREVIOUS SOIL BORING

— GROUNDWATER MONITORING WELL

NA — NOT APPLICABLE

FIGURE 2.1

SITE 510.8

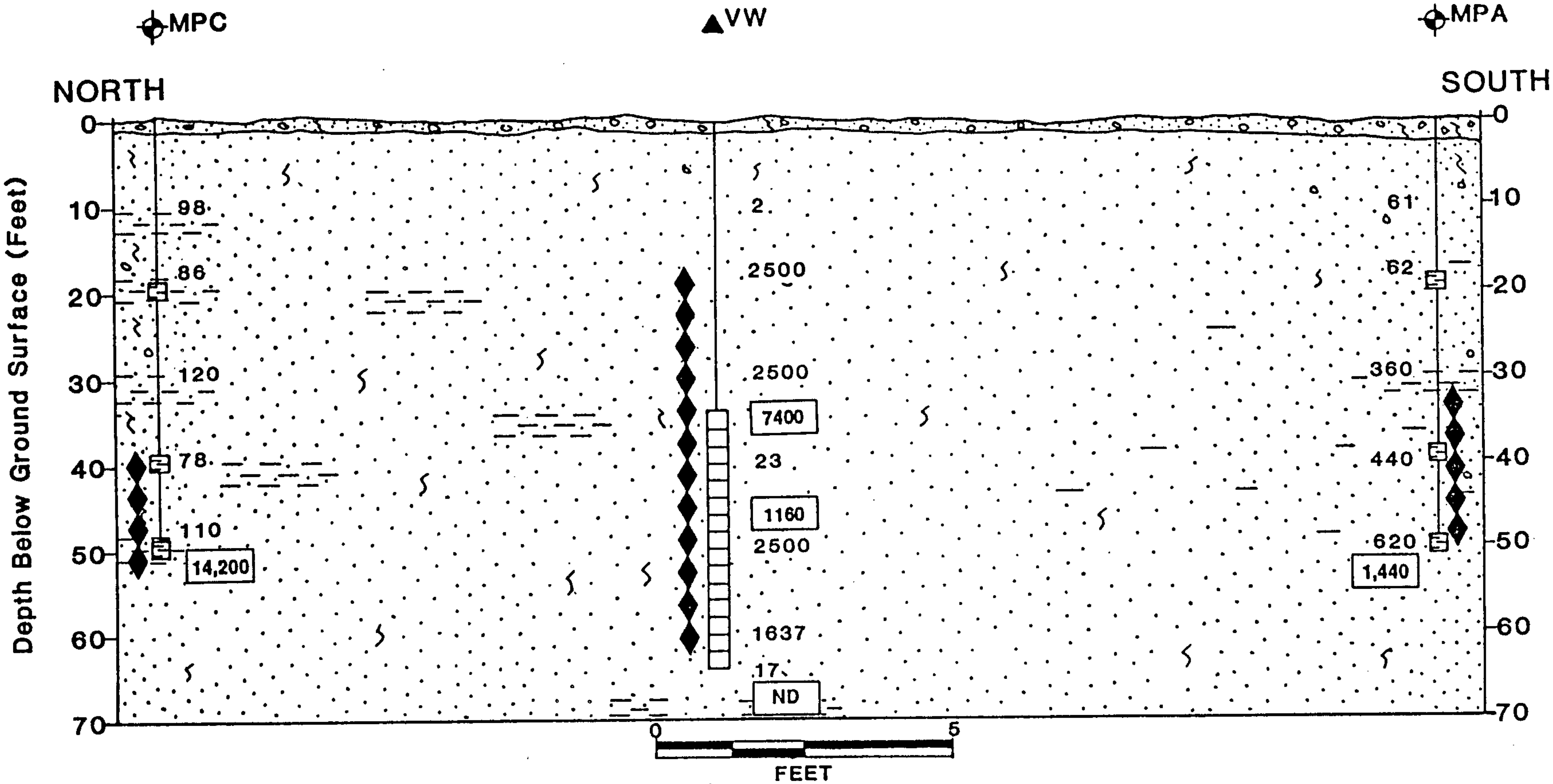
AS-BUILT SITE PLAN

HILL AFB, UTAH

ENGINEERING-SCIENCE, INC.

Denver, Colorado

93DN1126, 03/08/94 at 09:45



LITHOLOGIC DESCRIPTION

SANDY GRAVEL | SAND | SILTY SAND | SAND WITH CLAY LENSES

LEGEND

- MPA — MONITORING POINT
- VW — INJECTION VENT WELL
- 620 — FIELD SCREENING RESULTS FOR TOTAL VOLATILE HYDROCARBONS (ppmv)
- 1160 — LABORATORY RESULTS FOR SOIL TOTAL PETROLEUM HYDROCARBONS (mg/kg)
- GEOLOGIC CONTACT, DASHED WHERE INFERRED
- MONITORING POINT SCREENED INTERVAL
- SCREENED WELL INTERVAL
- PHYSICAL EVIDENCE OF HYDROCARBON CONTAMINATION

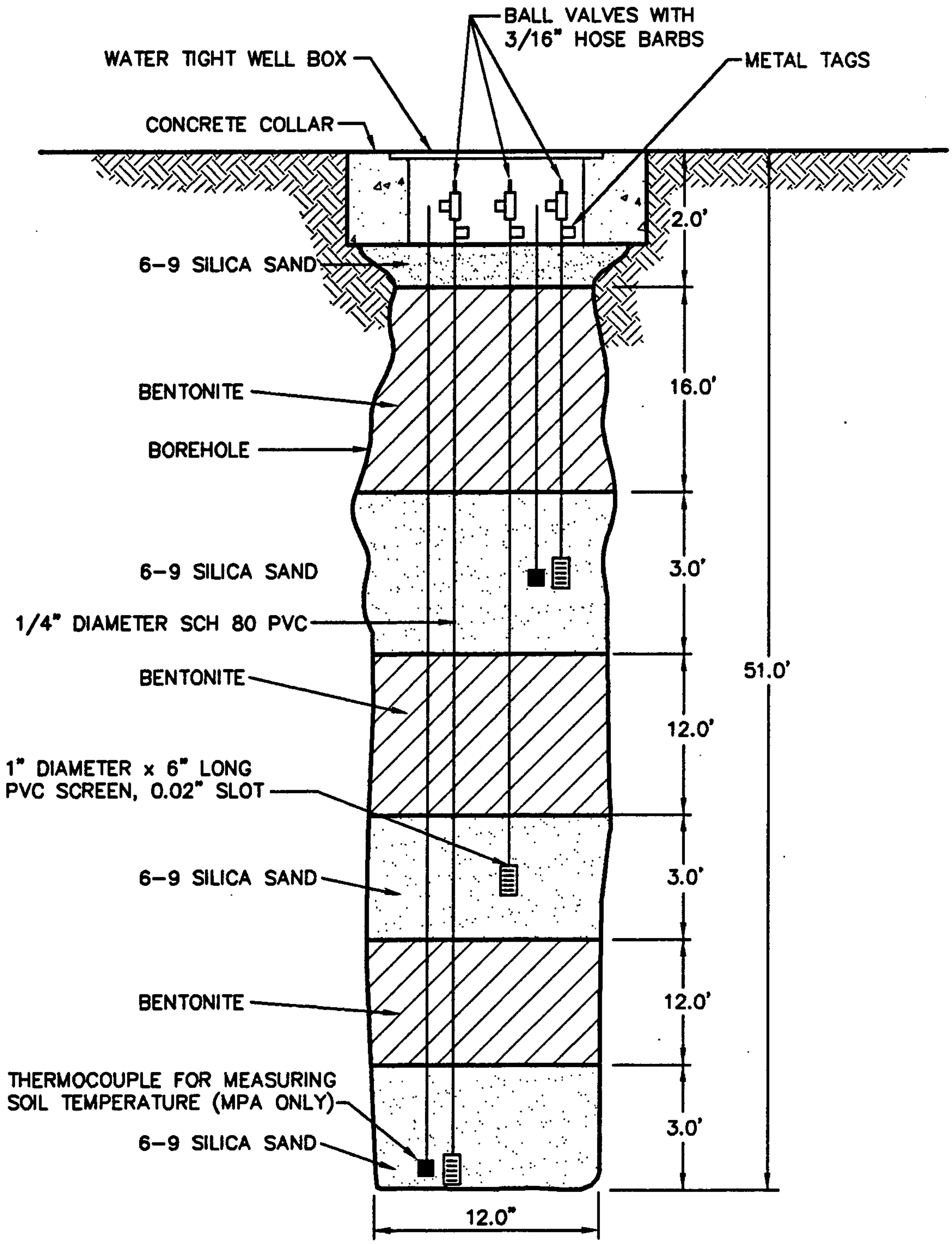
Note: VW data from EA Engineering,Science, and Technology, 1992a.

FIGURE 2.2

SITE 510.8 GEOLOGIC CROSS SECTION

HILL AFB, UTAH

ENGINEERING-SCIENCE, INC.
Denver, Colorado



NOT TO SCALE

FIGURE 2.3
SITE 510.8

AS-BUILT MONITORING POINT MPB CONSTRUCTION DETAIL

HILL AFB, UTAH

ENGINEERING-SCIENCE, INC.

Denver, Colorado

93DN1120, 02/18/94 at 14:10

unit are shown in Figure 2.4. After blower installation and startup, ES engineers provided an O&M manual to base personnel. A copy of the O&M manual is provided in Appendix B.

2.2 Soil and Soil Gas Sampling Results

Soils at this site primarily consist of well-graded sand with occasional clayey sand lenses. Groundwater was reported to be at 86 feet bgs (EA Engineering, Science, and Technology, 1992b). More detailed geologic information for Site 510.8 can be found in the geologic cross section (Figure 2.2) and the geologic boring logs (Appendix A).

During the ES drilling program, contaminated soils were identified based on visual appearance, odor, and results of total hydrocarbon analyzer field screening for volatile organic compounds (VOCs). Stoddard® solvent-contaminated soils were encountered at MPA from 30 to 50 feet bgs and at MPC from 40 to 50 feet bgs. No solvent contamination was discovered while drilling at MPB. During the previous site investigation, EA encountered solvent-contaminated soils in the VW from 20 to 60 feet bgs and in EA-MW1 from 7 to 30 feet bgs (EA Engineering, Science, and Technology, 1992b).

Soil samples for laboratory analysis were collected from 18-inch split-spoon samplers with 2-inch-diameter brass liners. Soil samples were screened for VOCs using a hydrocarbon analyzer to determine the presence of contamination and to select samples for laboratory analysis. Soil samples for laboratory analysis were collected from MPA, MPB, and MPC at depths of 49, 39, and 49 feet bgs, respectively.

Soil gas samples were collected from the VW, at 40 feet bgs from MPA, and at 35 feet bgs from MPB. Soil gas samples were collected using 3-liter Tedlar® bags and vacuum chambers. After the samples were collected into Tedlar® bags, they were transferred to 1-liter SUMMA® canisters and shipped to the laboratory.

Soil samples were shipped via Federal Express® to the Pace, Inc. laboratory in Novato, California for chemical and physical analysis. Soil samples were analyzed for TRPH, BTEX, iron, alkalinity, pH, total Kjeldahl nitrogen (TKN), phosphates, and several physical parameters. Soil gas samples were shipped via Federal Express® to Air Toxics, Inc. in Folsom, California for TVH and BTEX analysis by EPA Method TO-3. The TVH analyses were referenced to JP-4 jet fuel. The results of these analyses are provided in Table 2.1.

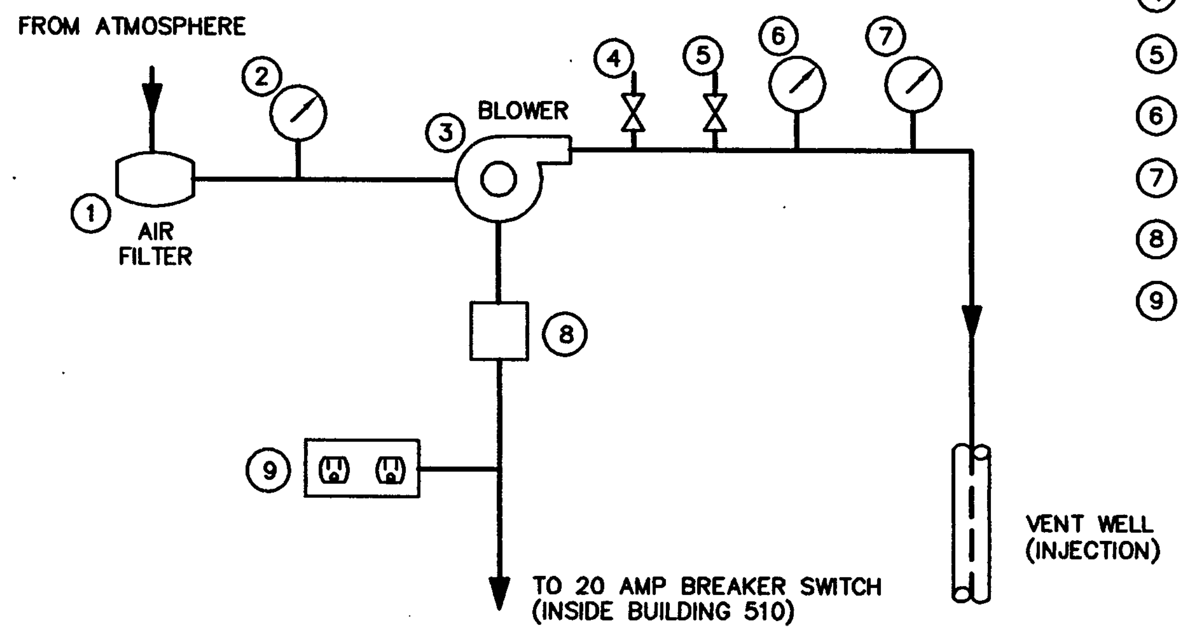
2.3 Exceptions To Test Protocol

Procedures described in the protocol document (Hinchee et al., 1992) were used to complete the pilot test at Site 510.8, with the following exception. No background point was installed at Site 510.8. Background conditions in uncontaminated soil at Hill AFB were established during prior research efforts (Hinchee and Miller, 1991).

2.4 Test Results

2.4.1 Initial Soil Gas Chemistry

Prior to initiating air injection, all MP screens, the VW, and MW-1 were purged, and initial oxygen, carbon dioxide, and TVH concentrations were determined using portable gas analyzers, as described in the technical protocol document (Hinchee



LEGEND

1. INLET AIR FILTER – SOLBERG® F-30P-150
2. VACUUM GAUGE (IN. H_2O)
3. 1-HP BLOWER – GAST® R4110N-50
4. MANUAL PRESSURE RELIEF (BLEED) VALVE 1 1/2" GATE
5. AUTOMATIC PRESSURE RELIEF VALVE
6. TEMPERATURE GAUGE (°F)
7. PRESSURE GAUGE (IN. H_2O)
8. FUSED DISCONNECT SWITCH-240V/SINGLE PHASE/30 AMP
9. WEATHERPROOF RECEPTACLE-110V

FIGURE 2.4
SITE 510.8

AS-BUILT
EXTENDED PILOT TEST BLOWER SYSTEM FOR AIR INJECTION

HILL AFB, UTAH

ENGINEERING-SCIENCE, INC.
Denver, Colorado

93DN1119, 02/14/93 at 14:35

TABLE 2.1

SITE 510.8

SOIL AND SOIL GAS ANALYTICAL RESULTS

HILL AFB, UTAH

Analyte (Units)[a]	Sample Location-Depth (feet below ground surface)		
Soil Hydrocarbons	MPA-49	MPB-39	MPC-49
TRPH (mg/kg)	1,440	ND (5.3)[b]	14,200
Benzene (mg/kg)	ND (0.08)	ND (0.0003)	ND (0.002)
Toluene (mg/kg)	ND (0.08)	ND (0.0003)	ND (0.002)
Ethylbenzene (mg/kg)	ND (0.08)	ND (0.0003)	ND (0.002)
Xylenes (mg/kg)	ND (0.2)	ND (0.0007)	ND (0.003)
Soil Gas Hydrocarbons	VW 34-64	MPA-40	MPB-35
TVH (ppmv) [c]	1,100	760	140
Benzene (ppmv)	ND (0.030)	ND (0.061)	ND (0.006)
Toluene (ppmv)	0.034	0.13	0.37
Ethylbenzene (ppmv)	ND (0.030)	0.11	0.055
Xylenes (ppmv)	0.15	0.51	0.62
Soil Inorganics	MPA-49	MPB-39	MPC-49
Iron (mg/kg)	4,400	4,200	5,580
Alkalinity (mg/kg as $CaCO_3$)	260	430	320
pH (units)	8.6	9.0	8.5
TKN (mg/kg)	120	61	120
Phosphates (mg/kg)	3,000	560	3,100
Soil Physical Parameters	MPA-49	MPB-39	MPC-49
Moisture (% wt.)	4.0	5.2	15.0
Gravel (%)	0	0	2.6
Sand (%)	86.5	66.1	69.6
Silt (%)	7.4	26.9	19.6
Clay (%)	6.1	7.0	8.2
Soil Temperature (°F)	MPA-20	MPA-50	
	62.0	60.8	

a/ TRPH=total recoverable petroleum hydrocarbons; mg/kg=milligrams per kilogram; TVH=total volatile hydrocarbons; ppmv=parts per million, volume per volume; $CaCO_3$=calcium carbonate; TKN=total Kjeldahl nitrogen, °F=degrees Fahrenheit.

b/ ND=not detected at method detection limit (in parentheses).

c/ TVH referenced to jet fuel (molecular weight=156).

et al., 1992). Table 2.2 summarizes the initial soil gas chemistry at Site 510.8. The results strongly indicate that biological fuel degradation has depleted the oxygen supply in solvent-contaminated vadose zone soils. During drilling and installation of the MPs, physical evidence of Stoddard® solvent contamination (i.e., hydrocarbon odor and staining) was noted at MPA from 30 to 50 bgs and at MPC from 40 to 50 feet bgs. At soil gas sampling locations in these solvent-contaminated zones (i.e., MPA-40, MPA-50, MPC-40, and MPC-50), oxygen had been depleted, with concentrations ranging from 0.0 to 5.4 percent, and carbon dioxide was present at elevated concentrations ranging from 12.0 to 15.0 percent. In contrast, oxygen concentrations collected from all other site locations ranged from 6.0 to 13.0 percent, and carbon dioxide concentrations ranged from 4.1 to 11.5 percent. Because the solvent-contaminated soil zones contained low oxygen and high carbon dioxide concentrations relative to those in uncontaminated soil, oxygen consumption and carbon dioxide accumulation in solvent-contaminated soils can be attributed to petroleum hydrocarbon biodegradation rather than the consumption of naturally occurring soil organic matter.

2.4.2 Soil Gas Permeability

A soil gas permeability test was conducted at Site 510.8 according to protocol procedures. Air was injected for 16 hours into the VW at a rate of approximately 62 scfm and an average pressure of approximately 27 inches of water. The pressure response at each MP is recorded in Table 2.3. Due to the gradual pressure increase with time and relatively long time to achieve steady-state pressures, the HyperVentilate® model was used to calculate air permeabilities (Hinchee et al., 1992). Calculated air permeability values ranged from 7.9 to 149 darcys, indicating that soil in solvent-contaminated zones at Site 510.8 is highly permeable to air flow and should be easily oxygenated. A radius of pressure influence of at least 25 feet was observed at all monitored depths, as demonstrated by the pressure response observed at MPB.

2.4.3 Oxygen Influence

The depth and radius of oxygen influence in the subsurface resulting from air injection into the central VW during pilot testing is the primary design parameter for full-scale bioventing systems. Optimization of full-scale and multiple VW systems requires pilot testing to determine the volume of soil that can be oxygenated at a given flow rate and VW screen configuration.

Table 2.4 describes the change in soil gas oxygen levels that occurred during the 16-hour soil gas permeability test. Significant increases in the oxygen concentration were measured at each MP interval with the exceptions of MPB-20 and MW-1, which both showed a slight decrease in oxygen concentration. The decreased oxygen levels observed at these points result from the outward movement of oxygen-deficient air from the more highly contaminated central portion of the site caused by the injection of air at the VW. The decrease in oxygen levels indicates significant air movement through the soils, and it is expected that oxygen will reach these points with continuous air injection. This relatively brief air injection period of 16 hours produced a radius of oxygen influence of at least 25 feet in site soils. It is likely that the radius of oxygen influence for a long-term bioventing system on this site will exceed 25 feet at all

TABLE 2.2

SITE 510.8

INITIAL SOIL GAS CHEMISTRY

HILL AFB, UTAH

MP	Depth (feet bgs)	O_2 (%)	CO_2 (%)	Field TVH (ppmv)	Lab TVH[a/] (ppmv)
VW	34-64	11.5	6.7	410	1,100
A	20	8.6	9.3	340	NS [b/]
A	40	0.0	15.0	500	760
A	50	5.4	12.0	500	NS
B	20	6.2	10.8	210	NS
B	35	10.2	8.0	260	140
B	50	11.8	7.0	250	NS
C	20	6.0	11.5	260	NS
C	40	0.7	15.0	350	NS
C	50	0.8	14.8	540	NS
MW-1	80-100	13.2	4.1	280	NS

a/ Lab TVH referenced to jet fuel (molecular weight=156).
b/ NS = not sampled.

TABLE 2.3

SITE 510.8

PRESSURE RESPONSE AT MONITORING POINTS DURING THE AIR PERMEABILITY TEST

HILL AFB, UTAH

	Pressure Response In MP (inches of water)									
Depth	MPA			MPB			MPC			MW-1
(feet bgs)	20	40	50	20	35	50	20	40	50	80-100
Elapsed Time (min.)										
1.0	0.2	1.8	1.6	0.0	0.16	0.7	0.15	1.7	0.9	0.78
2.0	0.2	2.6	2.9	0.08	0.4	1.25	0.2	2.9	2.2	0.70
3.0	--[a/]	--	--	0.13	0.7	1.6	0.3	3.4	3.4	0.72
4.0	0.3	3.4	3.9	0.17	0.9	1.95	--	--	--	0.73
5.0	0.35	3.8	4.8	--	--	--	0.4	4.2	4.3	--
6.0	0.35	3.8	4.8	0.27	1.1	2.4	--	--	--	0.83
7.0	--	--	--	0.36	1.35	2.65	0.5	4.6	5.5	0.88
8.0	0.5	4.3	5.6	0.42	1.55	2.9	--	--	--	0.92
9.0	--	--	--	--	--	--	0.6	5.0	6.4	--
10	0.6	4.4	6.4	0.5	1.8	3.25	--	--	--	1.0
30	0.6	5.6	8.2	0.42	2.35	4.2	0.6	6.2	9.6	1.0
60	0.6	6.0	8.9	0.59	2.75	4.8	0.7	6.7	10.25	1.35
90	0.6	6.2	9.1	0.62	2.95	5.2	0.7	6.8	10.5	1.6
125	0.6	6.3	9.4	0.6	3.0	5.4	0.7	7.0	10.75	1.8
228	0.5	6.0	9.0	0.34	2.6	5.1	0.4	6.8	10.5	1.5

a/ -- denotes no reading taken at this time.

A7-4-46

TABLE 2.4
SITE 510.8
INFLUENCE OF AIR INJECTION AT VENT WELL
ON MONITORING POINT OXYGEN LEVELS
HILL AFB, UTAH

MP	Distance From VW (ft)	Depth (feet bgs)	Initial O_2(%)	Final O_2(%)[a/]
A	12.08	20	8.6	20.3
A	12.08	40	0.0	20.3
A	12.08	50	5.2	20.6
B	25.0	20	6.2	5.5
B	25.0	35	10.0	19.0
B	25.0	50	11.8	20.4
C	9.41	20	6.0	20.6
C	9.41	40	0.7	20.6
C	9.41	50	0.8	19.7
MW-1	14.5	80-100	13.2	12.6

a/ Duration of air injection= 16 hours.

depths, and that the entire contaminated region is being supplied with oxygen. Future monitoring at this site will better define the treatment radius.

2.4.4 *In Situ* Respiration Rates

In situ respiration testing was performed at Site 510.8 according to protocol document procedures. Air admixed with approximately 8-percent helium, an inert tracer gas, was injected into MP screened intervals MPA-40, MPA-50, MPB-35, and MPC-50 for a 21.5-hour period at a rate of approximately 1 scfm per screened interval to deliver oxygen to solvent-contaminated soils. At the end of the 21.5-hour period, air injection ceased and changes in soil gas composition were monitored over time. Oxygen, TVH, carbon dioxide, and helium were measured over a period of 72 hours following the air injection period. The measured rates of oxygen utilization were then used to estimate the aerobic fuel biodegradation rates at Site 510.8. The results of *in situ* respiration testing are presented in Figures 2.5 through 2.8. Table 2.5 provides a summary of the observed oxygen utilization rates.

Because helium is a conservative, inert gas, the change in helium concentrations over time can be useful in determining if oxygen diffusion is responsible for a portion of the oxygen lost from each MP, or if leakage is occurring due to improper MP construction. Figures 2.5 through 2.8 compare oxygen utilization and helium retention. Helium was lost at rapid rates over the first 1,000 minutes of the *in situ* respiration test. However, the rate of helium loss was much lower for the remainder of the test, indicating that MP construction was sound and no major leakage or short-circuiting had occurred. Because the *in situ* respiration test was performed shortly after the soil gas permeability and oxygen influence test, the entire vadose zone had been oxygenated within a minimum 25-foot radius from the VW. Therefore, it is highly probable that the gradient of oxygen diffusion opposed that of helium diffusion during this test. Oxygen will diffuse from uncontaminated soils at the perimeter of the site into contaminated soil as oxygen is consumed in the contaminated soil regions. Conversely, helium will diffuse from regions of contaminated soil, where it was injected, toward the outlying uncontaminated soil. Thus, the observed oxygen loss can be attributed entirely to bacterial respiration.

At Site 510.8, only an estimated 140 mg of fuel per kg of soil can be degraded each year. This value is the average of the fuel consumption rates calculated for every point at which a respiration test was conducted. The MP-specific fuel consumption rates were calculated using observed oxygen utilization rates, estimated air-filled soil porosities, and a conservative ratio of 3.5 mg of oxygen consumed for every 1 mg of fuel biodegraded. Oxygen loss occurred at slow linear rates, ranging from 0.0001 to 0.0009 percent per minute. The air-filled soil porosities, calculated for each sampling point, ranged from 0.089 to 0.2 liter of air per kg of soil. The low initial oxygen levels and elevated carbon dioxide levels are the most convincing evidence that biodegradation is occurring at this site.

2.5 Recommendations

Initial bioventing tests at Site 510.8 indicate that oxygen has been depleted in solvent-contaminated soils, and that oxygen can be uniformly distributed through these soils by injecting air into the VW. Although results of the *in situ* respiration test were

Figure 2.5
Respiration Test
Oxygen and Helium Concentrations
Site 510.8, MPA-40
Hill AFB, Utah

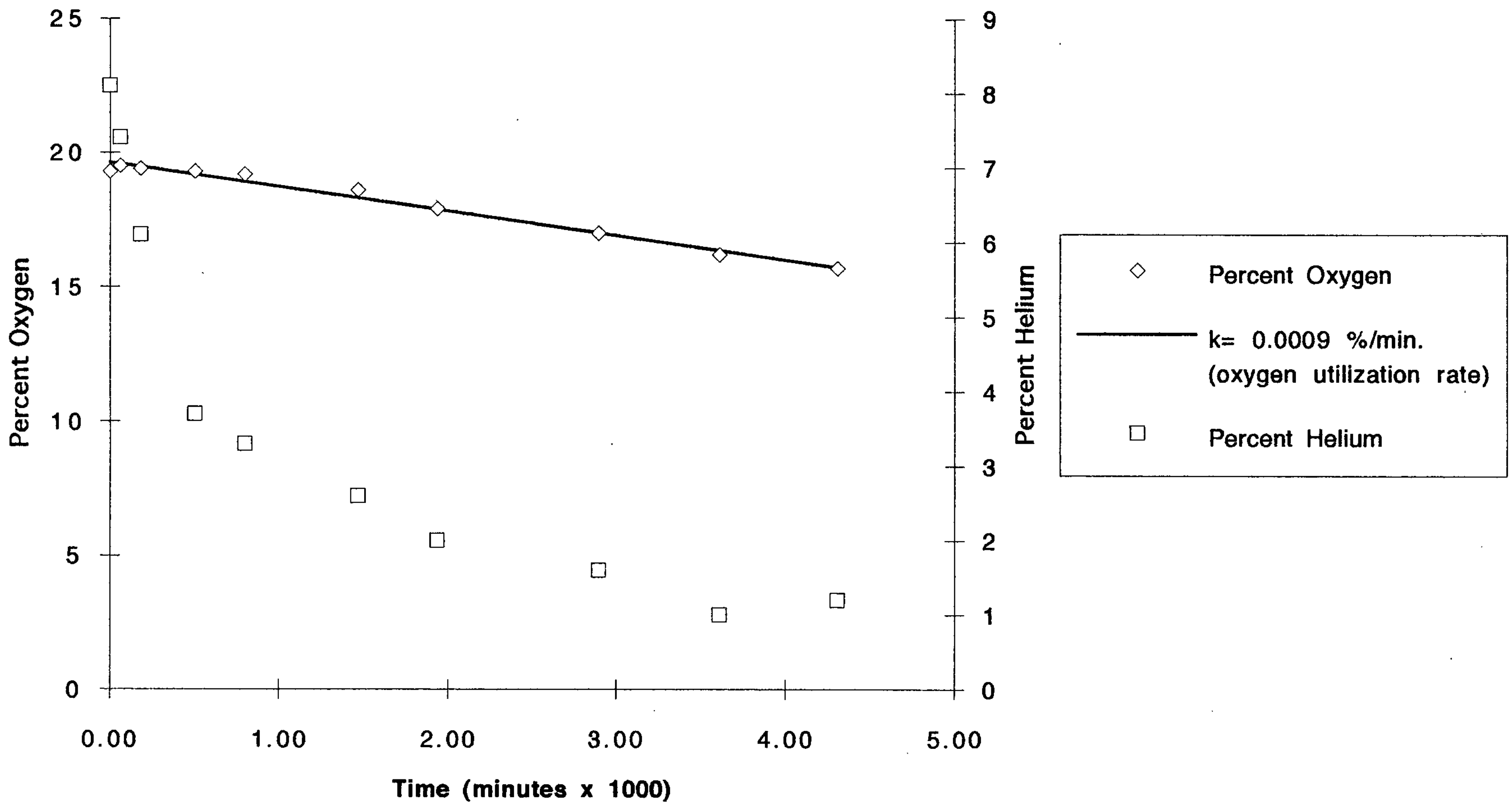


Figure 2.6
Respiration Test
Oxygen and Helium Concentrations
Site 510.8, MPA-50
Hill AFB, Utah

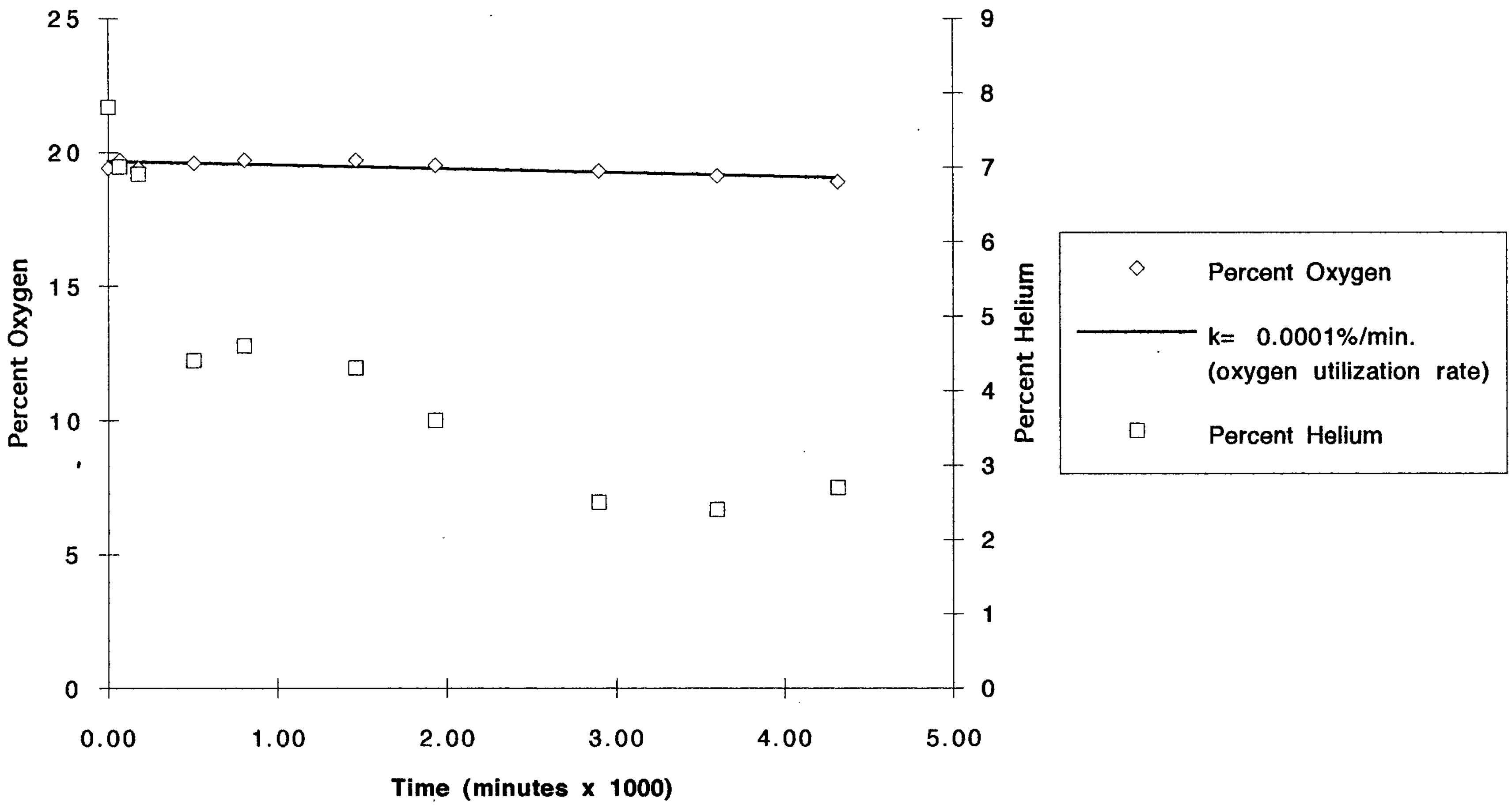


Figure 2.7
Respiration Test
Oxygen and Helium Concentrations
Site 510.8, MPB-35
Hill AFB, Utah

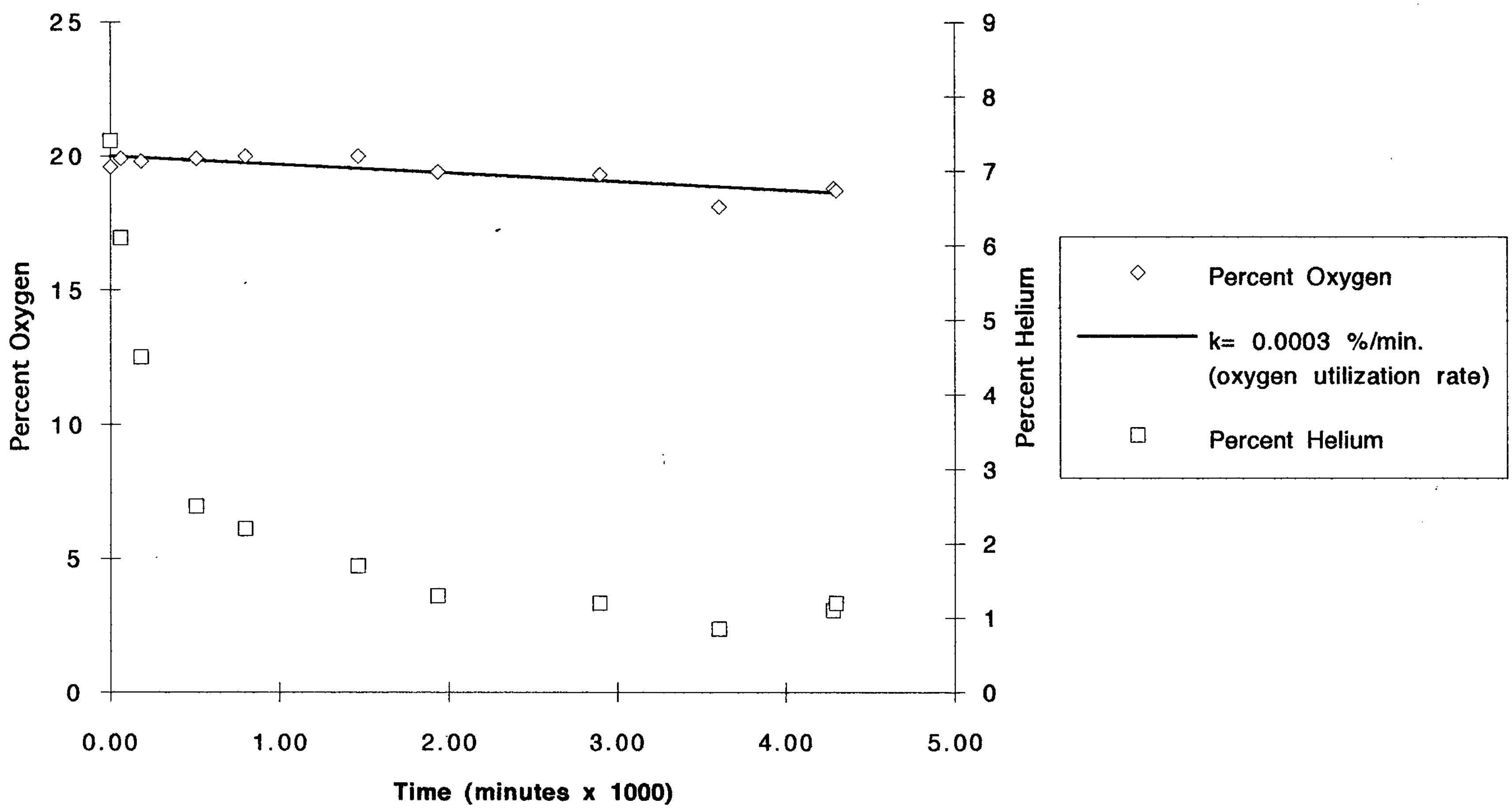


Figure 2.8
Respiration Test
Oxygen and Helium Concentrations
Site 510.8, MPC-50
Hill AFB, Utah

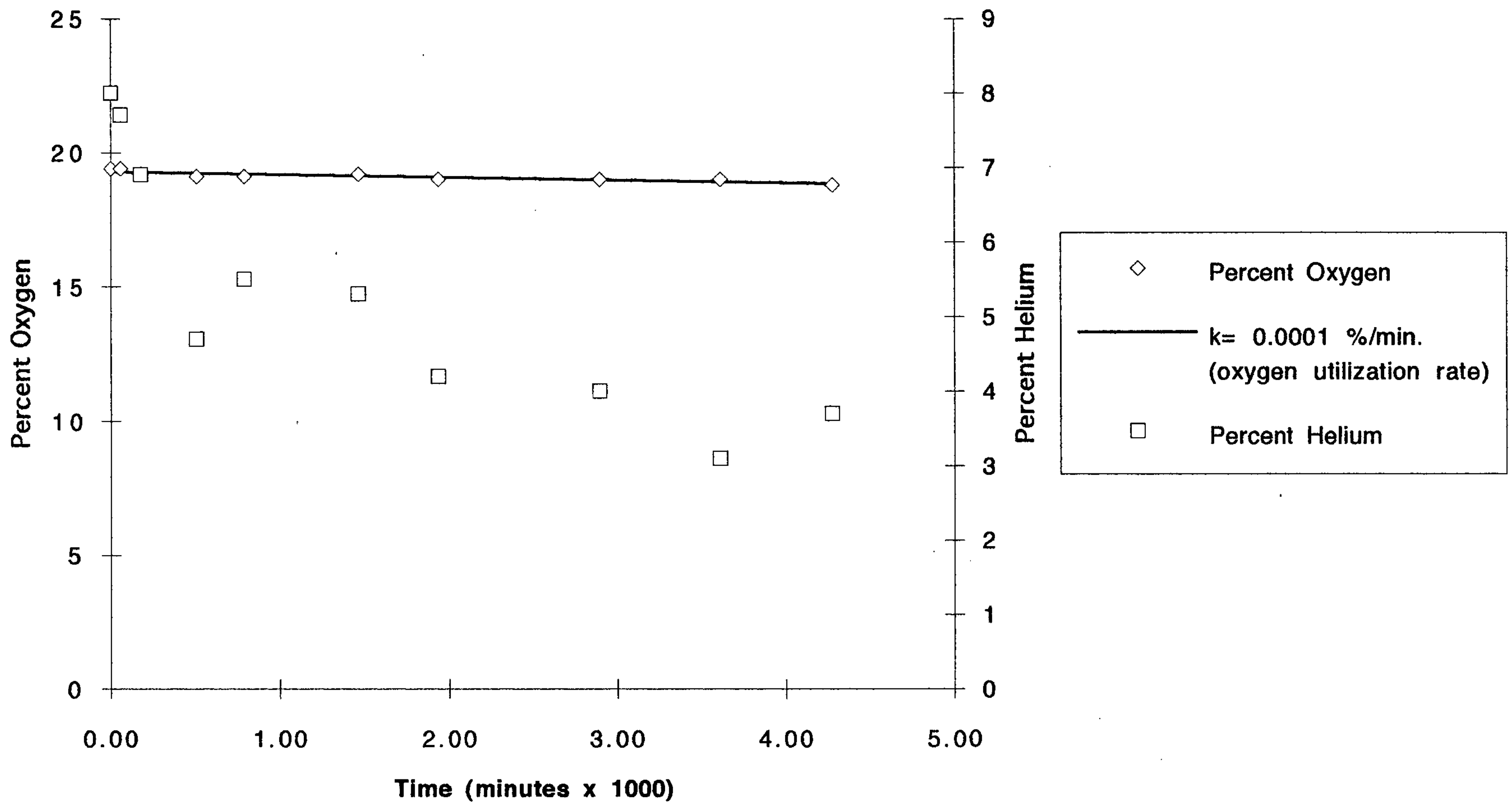


TABLE 2.5
SITE 510.8
OXYGEN UTILIZATION RATES
HILL AFB, UTAH

MP	O_2 Loss[a/] (%)	Test[b/] Duration (min)	O_2 Utilization[c/] Rate (%/min)
MPA-40	3.6	4310	0.0009
MPA-50	0.5	4310	0.0001
MPB-35	0.9	4300	0.0003
MPC-50	0.6	4280	0.0001

a/ Actual measured oxygen loss.
b/ Elasped time from beginning of test to time when minimum oxygen concentration was measured.
c/ Values based on linear regression (Figures 2.5 through 2.8).

inconclusive, air injection may be an effective method of stimulating aerobic petroleum solvent biodegradation. AFCEE has recommended that air injection continue on this site to determine the long-term radius of oxygen influence and the effect of time, available nutrients, and changing temperatures on solvent biodegradation rates.

A 1-HP regenerative blower has been installed at the site (Figure 2.1) for continuous air injection. In March 1994, ES will return to the site to sample and analyze the soil gas and conduct a repeat respiration test. In August 1994, a final respiration test will be conducted, and soil and soil gas samples will be collected from the site to determine the degree of remediation achieved during the first year of *in situ* treatment.

Based on the results of the first year of pilot-scale bioventing, AFCEE will recommend one of three options:

1. Continue operation of the bioventing system for full-scale remediation of the site.
2. If final soil sampling indicates significant contaminant removal has occurred, AFCEE may recommend additional sampling to confirm that cleanup criteria have been achieved.
3. If significant difficulties or poor results are encountered during bioventing at this site, AFCEE could recommend the removal of the blower system and proper abandonment of the VWs and MPs.

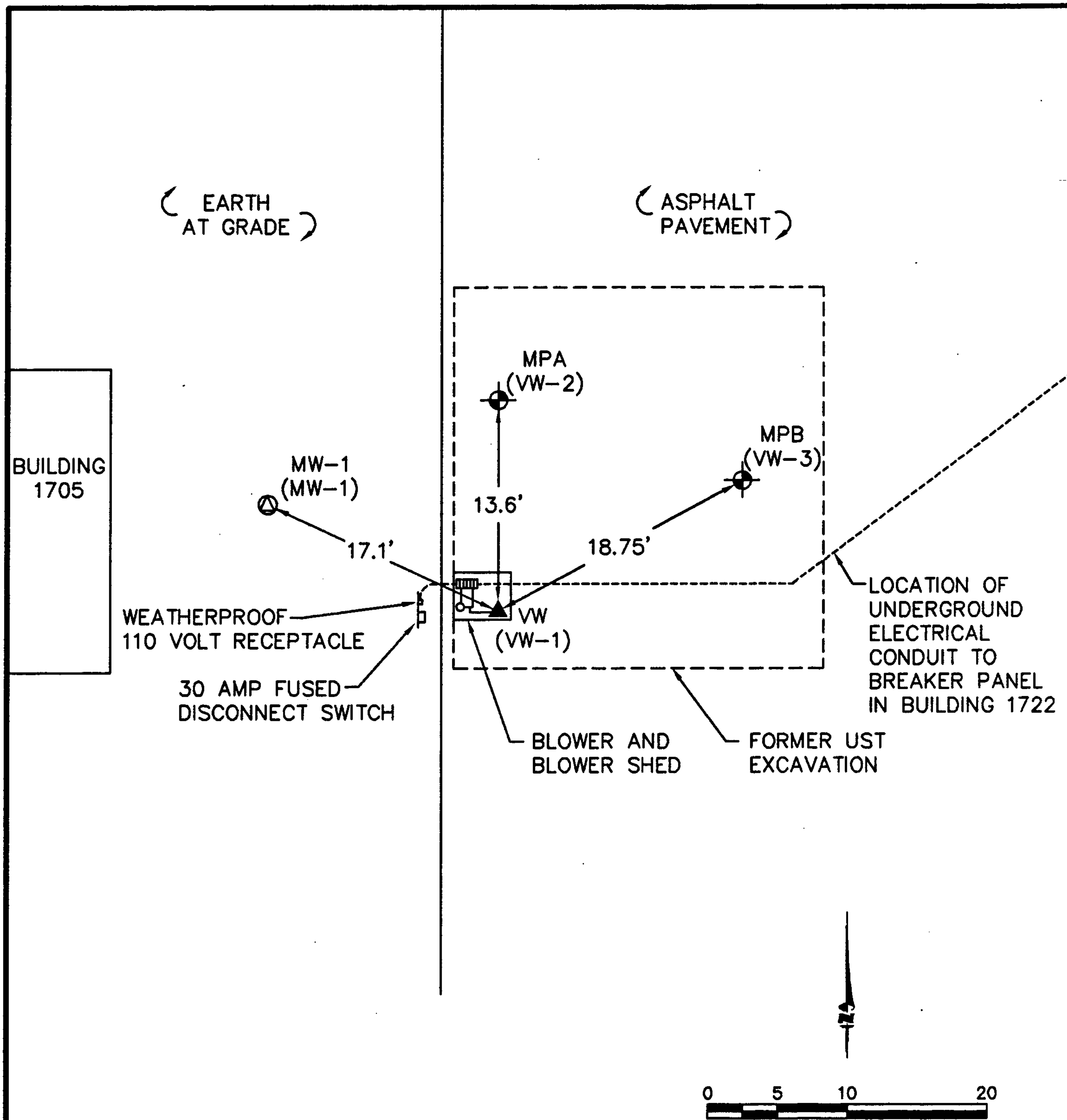
3.0 SITE 1705

3.1 Pilot Test Design

This section describes the final design and installation of the bioventing system at Site 1705. One VW, two MPs, and one groundwater monitoring well were installed at the site by another Air Force contractor in November 1992, prior to ES involvement. ES installed a blower unit at the site during initial bioventing pilot testing in July 1993. Figure 3.1 depicts the locations of the VW, MPs, groundwater monitoring well, and the blower unit.

3.1.1 Air Injection Vent Well

The air injection VW was installed by another Air Force contractor following procedures described in the AFCEE bioventing protocol document (Hinchee et al., 1992). The location of the VW is illustrated in Figure 3.1, and construction details are included in Appendix A. The VW was constructed using 4-inch-diameter, Schedule 40 PVC casing, with 10 feet of 0.020-inch-slotted PVC screen installed from 10 to 20 feet bgs. The annular space between the well casing and borehole was filled with number 10-20 filter pack sand from 8 to 23 feet bgs. A 1.5-foot layer of granular bentonite was placed above the sand and overlaid with 5.5 feet of cement/bentonite grout. One foot of concrete was used to fill the annular space to the existing ground surface. The top of the well was completed using a flush-mounted metal well protector set in concrete (Radian Corporation, 1993).



LEGEND

MPA (VW-2) – ES NOMENCLATURE (RADIAN NOMENCLATURE)

– GROUNDWATER MONITORING WELL

– AIR INJECTION WELL

– VAPOR MONITORING POINT

FIGURE 3.1

SITE 1705

AS-BUILT SITE PLAN

HILL AFB, UTAH

ENGINEERING-SCIENCE, INC.

Denver, Colorado

94DN0151, 03/07/94 at 14:40

3.1.2 Monitoring Points

Two MPs were installed at Site 1705 by another Air Force contractor prior to ES involvement (Radian Corporation, 1993). The screened intervals at MPA and MPB were installed at 13 and 15 feet bgs, respectively. Construction details for the MPs are included in Appendix A. Each MP monitoring interval was constructed using a 18-inch section of 1.5-inch-diameter PVC well screen and 0.25-inch inside-diameter plastic tubing extending to the ground surface. Each screen was installed in a bed of number 10-20 sand. A 2-foot layer of bentonite (hydrated in place) was placed on top of the sand. Cement/bentonite grout was placed in the annular space on top of the bentonite to 1 foot bgs. Concrete was placed in the annular space from 1 foot bgs to the ground surface. The tops of both MPs were completed with flush-mounted metal well protectors set in the concrete. Groundwater monitoring well MW-1 was also used as a vapor MP during the initial pilot testing. Construction details for MW-1 also are included in Appendix A.

3.1.3 Blower Unit

A 1-HP Gast® regenerative blower unit was installed at Site 1705 for the oxygen influence test and the extended pilot test. The blower is energized by 240-volt, single-phase, 30-amp line power from a breaker box in Building 1722, adjacent to the site, and is housed in a weatherproof enclosure. The extended pilot test blower is currently injecting air at a flow rate of approximately 30 scfm for the extended pilot test. The configuration, instrumentation, and specifications for the extended pilot test unit are shown in Figure 3.2. After blower installation and startup, ES engineers provided an O&M manual to base personnel. A copy of the manual is provided in Appendix B.

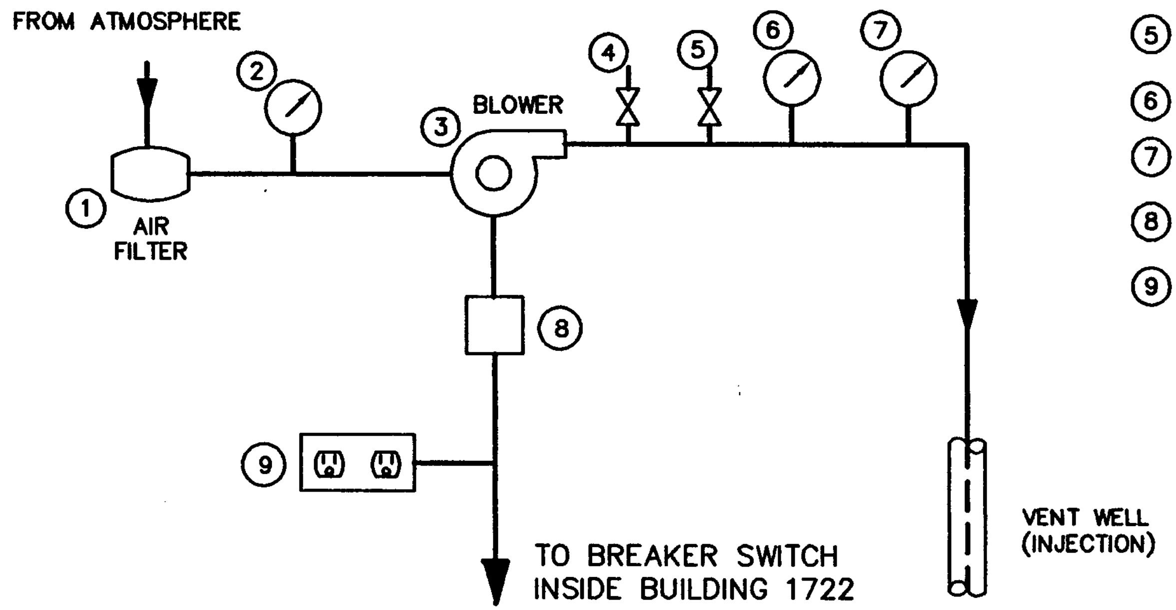
3.2 Soil and Soil Gas Sampling Results

Based on a site investigation by Radian Corporation (1993), hydrocarbon contamination appears to have migrated to a depth of 23 feet bgs southwest of the former UST area. The depth to groundwater was reported to be approximately 25 feet bgs in November 1992. Soils at Site 1705 are mostly fine- to medium-grained sand, with some lenses of sandy silt. Soil boring logs are included in Appendix A. Results of laboratory soil sampling are summarized in Table 3.1. TRPH concentrations ranged from nondetect (< 10 mg/kg) to 13,200 mg/kg.

Laboratory soil gas samples were collected by ES from the VW, MPA, and MPB. Soil gas samples were collected using 3-liter Tedlar® bags and vacuum chambers. After the samples were collected into Tedlar® bags, they were transferred to 1-liter SUMMA® canisters and shipped to the laboratory. Soil gas samples were shipped via Federal Express® to Air Toxics, Inc. in Folsom, California for TVH and BTEX analysis by EPA Method TO-3. The TVH analyses were referenced to gasoline. The results of these analyses are provided in Table 3.1.

3.3 Exceptions To Test Protocol

Procedures described in the protocol document (Hinchee et al., 1992) were used to complete the pilot test at Site 1705, with the following exceptions. Initial soil sampling performed by other Air Force contractors deviated from the protocol. TRPH samples were analyzed using a modified EPA Method 8015, rather than with Method 418.1 as



LEGEND

1. INLET AIR FILTER – SOLBERG® F-30P-150
2. VACUUM GAUGE (IN. H_2O)
3. 1-HP BLOWER – GAST® R4110N-50
4. MANUAL PRESSURE RELIEF (BLEED) VALVE 1 1/2" GATE
5. AUTOMATIC PRESSURE RELIEF VALVE
6. PRESSURE GAUGE (IN. H_2O)
7. TEMPERATURE GAUGE (°F)
8. FUSED DISCONNECT SWITCH–240V/SINGLE PHASE/30 AMP
9. WEATHERPROOF RECEPTACLE–110V

FIGURE 3.2
SITE 1705

AS-BUILT
EXTENDED PILOT TEST BLOWER SYSTEM FOR AIR INJECTION

HILL AFB, UTAH

ENGINEERING-SCIENCE, INC.
Denver, Colorado

93DN1117, 02/18/94 at 14:05

TABLE 3.1

SITE 1705

SOIL AND SOIL GAS ANALYTICAL RESULTS

HILL AFB, UTAH

Analyte (Units)[a/]	Sample Location-Depth (feet below ground surface)		
Soil Hydrocarbons[b/]	VW-10	MPA-23-25	MPB-11-13
TRPH (mg/kg)	13,200	ND (0.01) [c/]	ND (0.01)
Benzene (mg/kg)	ND (0.025)	ND (0.01)	ND (0.01)
Toluene (mg/kg)	ND (0.025)	ND (0.01)	ND (0.01)
Ethylbenzene (mg/kg)	ND (0.025)	ND (0.01)	ND (0.01)
Xylenes (mg/kg)	0.36	ND (0.01)	ND (0.01)
Soil Gas Hydrocarbons	VW-10-20	MPA-13	MPB-15.4
TVH (ppmv) [d/]	110	7.7	13
Benzene (ppmv)	0.024	0.008	0.004
Toluene (ppmv)	0.035	0.014	0.007
Ethylbenzene (ppmv)	0.025	ND (0.002)	0.006
Xylenes (ppmv)	0.14	0.007	0.013
Soil Physical Parameters[b/]	VW-15-20	MPA-6-12	MPB-5-10
Moisture (% wt.)	8.3 [e/]	10.3 [f/]	3.3 [g/]
Gravel (%)	0	1	3
Sand (%)	70	71	70
Silt and Clay (%)	30	28	27

a/ TRPH=total recoverable petroleum hydrocarbons; mg/kg=milligrams per kilogram; TVH=total volatile hydrocarbons; ppmv=parts per million, volume per volume.

b/ Radian Corporation, 1993.

c/ ND=not detected at method detection limit (in parentheses).

d/ TVH referenced to gasoline (molecular weight=100).

e/ Sample collected at 10 feet bgs.

f/ Sample collected at 23-25 feet bgs.

g/ Sample collected at 11-13 feet bgs.

specified in the protocol. Soil samples collected during the site investigation were not analyzed for inorganic parameters specified in the protocol. These analyses will be performed during the 12-month sampling event. No thermocouples were installed at Site 1705. Also, no background points were installed at Site 1705. Background conditions in uncontaminated soil at Hill AFB have already been established during prior research efforts (Hinchee and Miller, 1991). Because initial soil gas samples from all monitoring locations contained high oxygen concentrations, no *in situ* respiration test was performed at Site 1705. Also, the air permeability test varied slightly from protocol procedures.

3.4 Test Results

3.4.1 Initial Soil Gas Chemistry

Prior to initiating air injection, the MPs, VW, and MW-1 were purged, and initial oxygen, carbon dioxide, and TVH concentrations were determined using portable gas analyzers, as described in the technical protocol document (Hinchee et al., 1992). Table 3.2 summarizes the initial soil gas chemistry at Site 1705. Oxygen was present at elevated concentrations, ranging from 16.8 to 17.6 percent, in all soil gas samples. Carbon dioxide was present at low levels, ranging from 2.6 to 3.3 percent. Field TVH concentrations were low, generally indicating the absence of fuel contamination. However, TRPH was detected at a concentration of 13,200 mg/kg in one soil sample collected from the VW (Table 3.1), indicating that zones of fuel-contaminated soil exist at Site 1705. It is possible that anaerobic, fuel-contaminated zones exist at Site 1705, but MP screens have not been set in these zones. To ensure that the entire former UST area is oxygenated, an extended blower system was installed at the site.

3.4.2 Soil Gas Permeability

A soil gas permeability test was conducted at Site 1705. The testing procedures differed slightly from protocol procedures because soil gas at Site 1705 was discovered to be naturally oxygenated prior to the initiation of the pilot testing. Air was injected into the VW for a period of approximately 3 weeks at a rate of approximately 70 scfm and an average pressure of approximately 19 inches of water. Pressure influence was not monitored until the end of this period, when a round of steady-state pressure readings were collected, and a steady-state permeability value was calculated. Pressures of 4.7, 4.5, and 5.9 inches of water were recorded at MPA, MPB, and MW-1, respectively. Baseline pressures at these points prior to air injection had been less than 0.1 inch of water. Using the steady-state method, a soil gas permeability value of 35 darcys was calculated, indicating that soil at Site 1705 is highly permeable to air flow. A radius of pressure influence of at least 18.75 feet was observed, as demonstrated by the pressure response observed at MPB. The actual radius of influence at Site 1705 under these conditions could be as great as 35 feet.

3.4.3 Oxygen Influence

The depth and radius of oxygen influence in the subsurface resulting from air injection into the central VW during pilot testing is the primary design parameter for full-scale bioventing systems. Optimization of full-scale and multiple VW systems

TABLE 3.2
SITE 1705
INITIAL SOIL GAS CHEMISTRY
HILL AFB, UTAH

MP	Depth (feet bgs)	O_2 (%)	CO_2 (%)	Field TVH (ppmv)	Lab TVH[a/] (ppmv)
VW	10-20	16.8	3.3	240	110
A	13	17.6	2.8	180	7.7
B	15.4	17.2	3.1	190	13
MW-1	22-42	17.4	2.6	190	NS[b/]

a/ Lab TVH referenced to gasoline (molecular weight=100).
b/ NS = not sampled.

requires pilot testing to determine the volume of soil that can be oxygenated at a given flow rate and VW screen configuration.

Table 3.3 describes the change in soil gas oxygen levels that occurred during approximately 3 weeks of air injection with the extended pilot testing system. Significant increases in oxygen concentrations were measured at each MP interval and MW-1. The observed radius of oxygen influence at this site is 18.75 feet, based on the results at MPB, but it appears that the radius of oxygen influence for the long-term bioventing system on this site could exceed 35 feet at all depths. It also appears that the entire potentially contaminated region is being supplied with oxygen. Future monitoring at this site will better define the treatment radius.

3.5 Recommendations

Initial bioventing tests at Site 1705 indicate that oxygen may already be present in fuel-contaminated soils at concentrations high enough to support aerobic fuel biodegradation. The oxygen concentrations can be increased in these soils by injecting air into the VW. Because there may be small undetected zones of anaerobic soil at the site, air injection should continue to fully oxygenate the site soils and to determine the effect of time, available nutrients, and changing temperatures on soil TRPH concentrations.

A 1-HP regenerative blower has been installed at the site (Figure 3.1) for continuous air injection. In March 1994, ES will return to the site to sample and analyze the soil gas. In August 1994, soil and soil gas samples will be collected from the site to determine the degree of remediation achieved during the first year of *in situ* treatment.

Based on the results of the first year of pilot-scale bioventing, AFCEE will recommend one of three options:

1. Continue operation of the bioventing system for full-scale remediation of the site.
2. If final soil sampling indicates significant contaminant removal has occurred, AFCEE may recommend additional sampling to confirm that cleanup criteria have been achieved.
3. If significant difficulties or poor results are encountered during the extended bioventing pilot test at this site, AFCEE could recommend the removal of the blower system and proper abandonment of the VWs and MPs.

4.0 SITE 40002

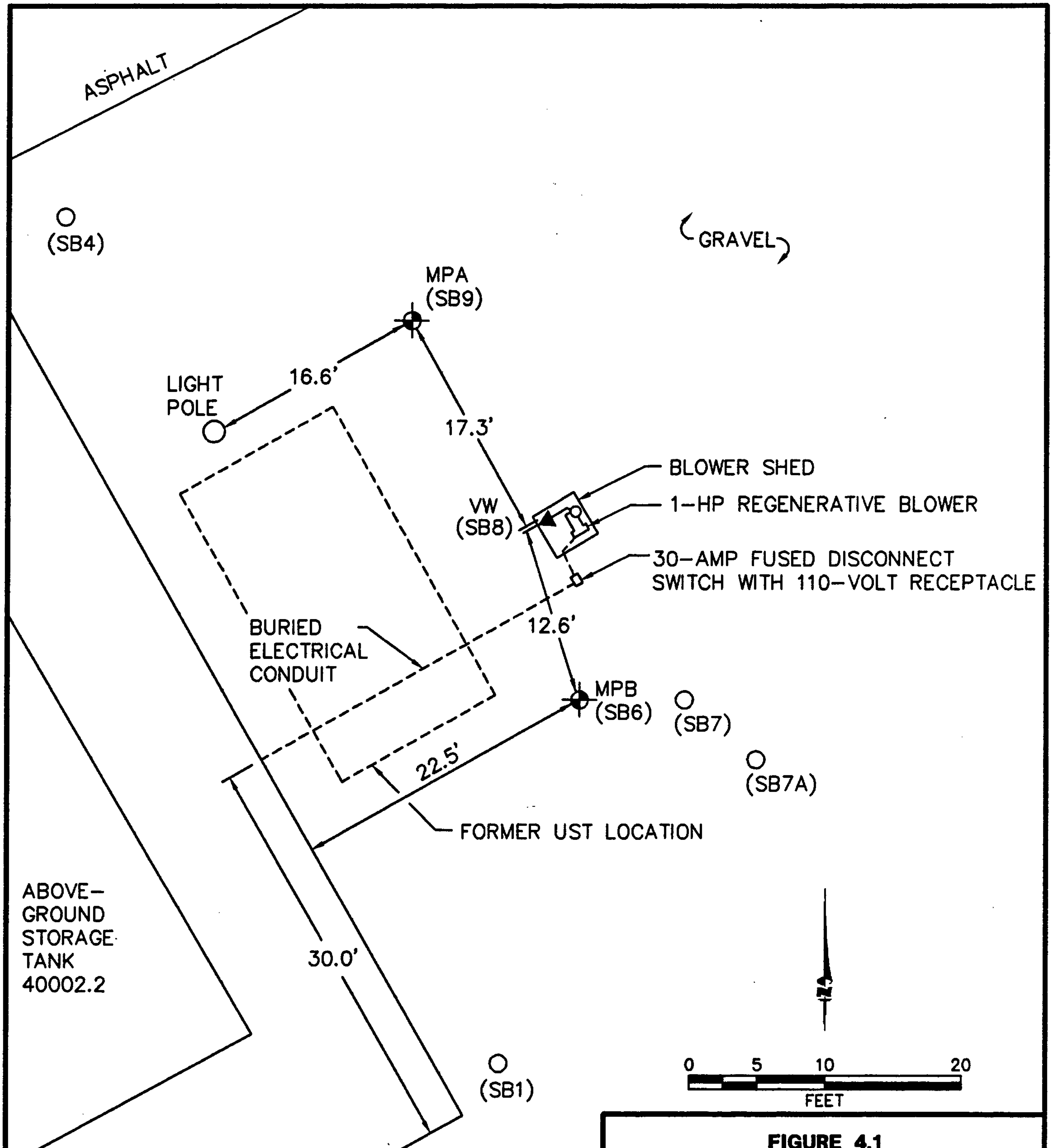
4.1 Pilot Test Design

This section describes the final design and installation of the bioventing system on Site 40002, located at the Utah Test and Training Range in western Utah. One VW and two MPs were installed at the site by the Salt Lake City office of ES in November 1992. ES-Denver installed a blower unit at the site in August 1993. Figure 4.1 depicts the locations of the VW, MPs, and blower unit installed at Site 40002.

TABLE 3.3
SITE 1705
INFLUENCE OF AIR INJECTION AT VENT WELL ON MONITORING POINT OXYGEN LEVELS
HILL AFB, UTAH

MP	Distance From VW (ft)	Depth (feet bgs)	Initial O_2(%)	Final O_2(%)[a/]
A	13.6	13	17.6	20.6
B	18.75	15.4	17.2	20.6
MW-1	17.1	22-42	17.4	20.6

a/ Reading taken after approximately 48 hours of air injection.



LEGEND

VW — ES REMEDIAL PHASE NOMENCLATURE
(SB8) — (ES INVESTIGATIVE PHASE NOMENCLATURE)
VW ▲ — AIR INJECTION VENT WELL
MPA — VAPOR MONITORING POINT
SB1 ○ — PREVIOUS SOIL BORING

FIGURE 4.1

SITE 40002

AS-BUILT SITE PLAN

UTAH TEST AND TRAINING RANGE

HILL AFB, UTAH

ENGINEERING-SCIENCE, INC.

Denver, Colorado

93DN1123, 03/07/94 at 14:30

4.1.1 Air Injection Vent Well

The air injection VW was installed by ES-Salt Lake following procedures described in the AFCEE bioventing protocol document (Hinchee et al., 1992). The location of the VW is illustrated in Figure 4.1, and construction details are included in Appendix A. The VW was constructed using 4-inch-diameter, Schedule 40 PVC casing, with 40 feet of 0.020-inch-slotted PVC screen installed from 5 to 45 feet bgs. The annular space between the well casing and borehole was filled with number 8 sand from 3 to 47.5 feet bgs. The remainder of the annular space was filled with cement/bentonite grout. The top of the well was then completed using a flush-mount metal well protector set in concrete (ES, 1993).

4.1.2 Monitoring Points

Two MPs were installed at Site 40002 by ES-Salt Lake at locations shown in Figure 4.1. Screened intervals at MPA were installed at 17 and 32 feet bgs, and those at MPB were installed at 16 and 32 feet bgs. Construction details for the MPs are included in Appendix A. Each MP monitoring interval was constructed using a 12-inch section of 1.5-inch-diameter PVC well screen and 3/8-inch polypropylene tubing extending to the ground surface. Each screen was bedded in a sand pack, and bentonite or cement grout seals were placed in the annular space between the sand packs to prevent soil gas short circuiting. The top of each MP was completed with a flush-mounted metal well protector set in concrete (ES, 1993).

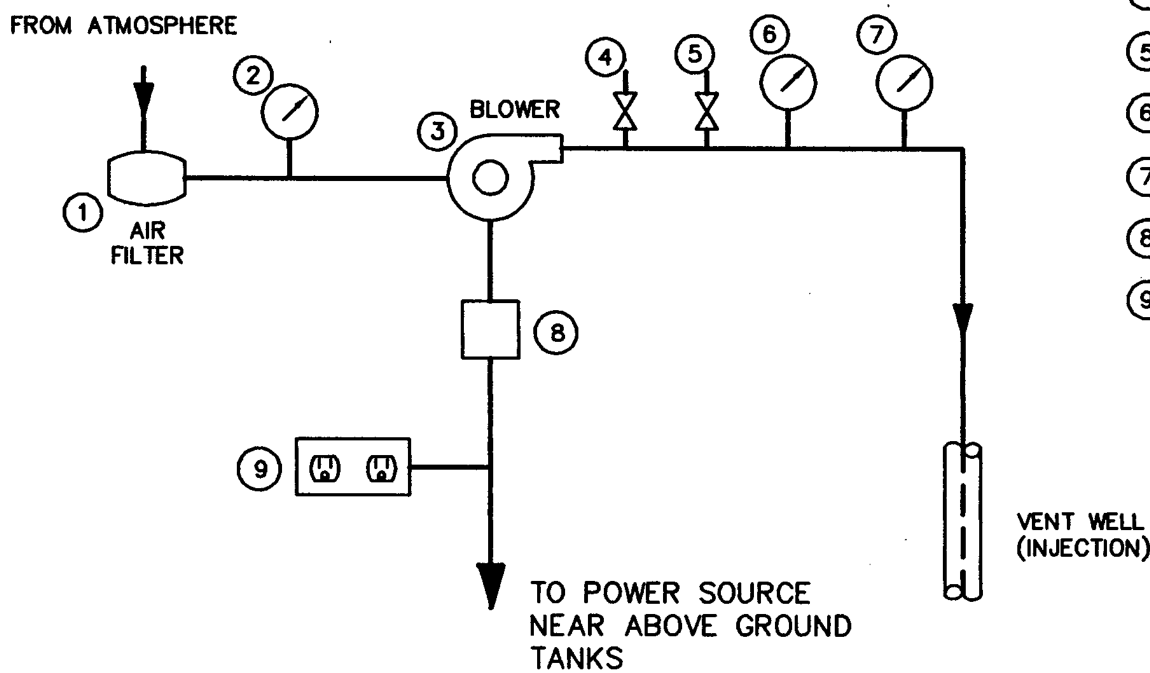
4.1.3 Blower Unit

A 1-HP Gast® regenerative blower unit was installed at Site 40002 for both the initial and extended pilot tests. The blower was energized by 240-volt, single-phase, 30-amp line power from a breaker box adjacent to the site, and is housed in a weatherproof enclosure. The blower is currently injecting air at a flow rate of approximately 45 scfm into the VW for the extended pilot test. The configuration, instrumentation, and specifications for the extended pilot test unit are shown on Figure 4.2. After blower installation and startup, ES engineers provided an O&M manual to base personnel. A copy of the manual is provided in Appendix B.

4.2 Soil and Soil Gas Sampling Results

Based on a site investigation by ES (January 1993), hydrocarbon contamination appears to have migrated to a depth of 47.5 feet bgs. After the removal of the USTs, a number of boreholes were placed in the vicinity to define the extent of contamination. Soils at Site 40002 consist of fine sand, with silt and clay at various depths. Soil boring logs are included in Appendix A. Results of laboratory soil sampling are summarized in Table 4.1. TRPH concentrations ranged from nondetect (<10 mg/kg) to 60,600 mg/kg.

Laboratory soil gas samples were collected by ES from the VW, MPA-17, and MPB-16. Soil gas samples were collected using 3-liter Tedlar® bags and vacuum chambers. After the samples were collected in Tedlar® bags, they were transferred to 1-liter SUMMA® canisters and shipped to the laboratory. Soil gas samples were shipped via Federal Express® to Air Toxics, Inc. in Folsom, California for TVH and



LEGEND

1. INLET AIR FILTER – SOLBERG® F-30P-150
2. VACUUM GAUGE (IN. H_2O)
3. 1-HP BLOWER – GAST® R4110N-50
4. MANUAL PRESSURE RELIEF (BLEED) VALVE 1 1/2" GATE
5. AUTOMATIC PRESSURE RELIEF VALVE
6. PRESSURE GAUGE (IN. H_2O)
7. TEMPERATURE GAUGE (°F)
8. FUSED DICONNECT SWITCH–240V/SINGLE PHASE/30 AMP
9. WEATHERPROOF RECEPTACLE – 110V

FIGURE 4.2
SITE 40002
AS-BUILT
EXTENDED PILOT TEST BLOWER SYSTEM FOR AIR INJECTION
UTAH TEST AND TRAINING RANGE
HILL AFB, UTAH

ENGINEERING-SCIENCE, INC.
Denver, Colorado

93DN1118, 03/07/94 at 14:30

TABLE 4.1
SITE 40002
SOIL AND SOIL GAS ANALYTICAL RESULTS
UTAH TEST AND TRAINING RANGE
HILL AFB, UTAH

Analyte (Units)[a]	Sample Location-Depth (feet below ground surface)		
Soil Hydrocarbons[b]	VW-13.5-15.5	MPA-13.5-15.5	MPB-14
TRPH (mg/kg)	60,600	23,400	ND (10.0) [c]
Benzene (mg/kg)	127	13.4	ND (0.01)
Toluene (mg/kg)	1,060	352	ND (0.01)
Ethylbenzene (mg/kg)	333	144	ND (0.01)
Xylenes (mg/kg)	2,309	1,444	ND (0.01)
Soil Gas Hydrocarbons	VW-5-45	MPA-17	MPB-16
TVH (ppmv) [d]	20,000	12,000	1,300
Benzene (ppmv)	ND (1.1)	ND (2.3)	ND (0.12)
Toluene (ppmv)	240	290	8.3
Ethylbenzene (ppmv)	26	8.8	0.68
Xylenes (ppmv)	220	100	16
Soil Physical Parameters[b]	VW-35-37	MPA-13.5-15.5	MPB-15-17
Moisture (% wt.)	12	23.2	19
Gravel (%)	0	NS [e]	0
Sand (%)	33	NS	22
Silt and Clay (%)	67	NS	78

a/ TRPH=total recoverable petroleum hydrocarbons; mg/kg=milligrams per kilogram; TVH=total volatile hydrocarbons; ppmv=parts per million, volume per volume.

b/ Engineering Science, 1993.

c/ ND=not detected at method detection limit (in parentheses).

d/ TVH referenced to gasoline (molecular weight=100).

e/ NS=not sampled.

BTEX analysis by EPA Method TO-3. The TVH analyses were referenced to gasoline. The results of these analyses are provided in Table 4.1.

4.3 Exceptions To Test Protocol

Procedures described in the protocol document (Hinchee et al., 1992) were used to complete the pilot test at Site 40002, with the following exceptions. TRPH samples were analyzed using a modified EPA Method 8015, rather than Method 418.1 as specified in the protocol. Soil samples collected during the site investigation were not analyzed for inorganic parameters specified in the protocol. These analyses will be performed during the 12-month sampling event. No thermocouples were installed at Site 40002. Also, no background points were installed at Site 40002. Background conditions at Hill AFB were established during prior research efforts (Hinchee and Miller, 1991). Soils at this location should be sufficiently similar to those at Hill AFB in their mineral and organic content to apply Hill AFB background conditions to Site 40002.

4.4 Test Results

4.4.1 Initial Soil Gas Chemistry

Prior to initiating air injection, all MP screens and the VW were purged, and initial oxygen, carbon dioxide, and TVH concentrations were determined using portable gas analyzers, as described in the technical protocol document (Hinchee et al., 1992). Table 4.2 summarizes the initial soil gas chemistry at Site 40002. The results strongly indicate that biological fuel degradation has depleted the oxygen supply in fuel-contaminated vadose zone soils. Oxygen concentrations from all sampling locations except MPB-32 were depleted, ranging from 2.3 to 6.0 percent. These locations also yielded elevated carbon dioxide concentrations, ranging from 9.2 to 13.8 percent, and elevated field TVH levels, ranging from 1,440 to 10,800 ppmv. In contrast, MPB-32 contained high oxygen, low carbon dioxide, and low field TVH levels (Table 4.2). Because the zones containing fuel-contaminated soil gas had lower oxygen and higher carbon dioxide concentrations relative to those in uncontaminated soil, oxygen consumption and carbon dioxide accumulation in fuel-contaminated soils can be attributed to petroleum hydrocarbon biodegradation rather than the consumption of naturally occurring soil organic matter.

4.4.2 Soil Gas Permeability

A soil gas permeability test was conducted at Site 40002 according to protocol procedures. Air was injected into the VW for approximately 2 weeks at a rate of 37 scfm and an average pressure of approximately 45 inches of water. Due to the low permeability of the soils at this site, no significant pressure influence was observed at any of the MP screens over the first 12 hours of air injection. At the end of the 2-week air injection period, a round of steady-state pressure readings was collected. A steady-state pressure of 0.1 inch of water was observed at MPA-17 and MPB-16. Pressures of 0.4 and 1.0 inch of water were recorded at MPA-32 and MPB-32, respectively. Baseline pressures at these points prior to air injection had been 0.0 inch of water. Using the steady-state method of determining soil gas permeability, a permeability value of 1.6 darcys was calculated, indicating that soil at Site 40002 has somewhat low

TABLE 4.2
SITE 40002
INITIAL SOIL GAS CHEMISTRY
UTAH TEST AND TRAINING RANGE
HILL AFB, UTAH

MP	Depth (feet bgs)	O_2 (%)	CO_2 (%)	Field TVH (ppmv)	Lab TVH[a/] (ppmv)
VW	5-45	4.6	11.7	10,800	20,000
A	17	2.8	13.8	9,800	12,000
A	32	6.0	9.2	2,400	NS[b/]
B	16	2.3	13.3	1,440	1,300
B	32	16.8	2.1	620	NS

a/ Lab TVH referenced to gasoline (molecular weight=100)
b/ NS = not sampled.

A7-4-53

permeabiltiy to air flow. Soils at the 32-foot depth have a higher permeability than those at the shallow screened depth. A radius of pressure influence of at least 17.3 feet was observed, as demonstrated by the pressure response observed at MPA.

4.4.3 Oxygen Influence

The depth and radius of oxygen influence in the subsurface resulting from air injection into the central VW during pilot testing is the primary design parameter for full-scale bioventing systems. Optimization of full-scale and multiple VW systems requires pilot testing to determine the volume of soil that can be oxygenated at a given flow rate and VW screen configuration.

Table 4.3 describes the change in soil gas oxygen levels that occurred during the first 12 hours of the soil gas permeability test and after approximately 2 weeks of air injection with the extended pilot testing system. Because there were no significant increases in oxygen concentration during the first 12 hours of the soil gas permeability test, the blower was allowed to inject air continuously for 2 weeks, and oxygen concentrations were measured thereafter. Oxygen concentrations increased significantly over this 2-week period. A radius of oxygen influence of 17 feet was observed in site soils. At a depth of 32 feet bgs, it appears that the long-term radius of oxygen influence will exceed 17 feet. However, the soil at 16 to 17 feet bgs appears to have very low permeability to air flow, and the actual long-term radius of oxygen influence at these depths may be limited to between 15 and 20 feet. Future monitoring at this site will better define the treatment radius.

4.4.4 *In Situ* Respiration Rates

In situ respiration testing was performed at Site 40002 according to protocol document procedures. Air admixed with approximately 4 percent helium, an inert tracer gas, was injected into the VW and MP screened intervals MPA-17, MPA-32, MPB-16, and MPB-32 for a 19.5-hour period at a rate of approximately 1 scfm per screened interval to deliver oxygen to fuel-contaminated soils. At the end of the 19.5-hour period, air injection ceased and changes in soil gas composition were monitored over time. Oxygen, TVH, carbon dioxide, and helium were measured over a period of 108 hours following the air injection period. The measured rates of oxygen utilization were then used to estimate the aerobic fuel biodegradation rates at Site 40002. The results of *in situ* respiration testing are presented in Figures 4.3 through 4.7. Table 4.4 provides a summary of the observed oxygen utilization rates.

Because helium is a conservative, inert gas, the change in helium concentrations over time can be useful in determining if oxygen diffusion is responsible for a portion of the oxygen lost from each MP, or if leakage is occurring due to improper MP construction. Figures 4.3 through 4.7 compare oxygen utilization and helium retention.

Helium was lost at rapid rates over the first 1,000 minutes of the respiration test. However, the rate of helium loss was much lower for the remainder of the test, indicating that MP construction was sound and no major leakage or short-circuiting had occurred. After the first 1,000 minutes of the test had passed, the rates of helium loss and oxygen loss were approximately equal at all points where a respiration test was conducted. Because helium diffuses approximately three times faster than oxygen, the

TABLE 4.3
SITE 40002
INFLUENCE OF AIR INJECTION AT VENT WELL ON MONITORING POINT OXYGEN LEVELS
UTAH TEST AND TRAINING RANGE
HILL AFB, UTAH

MP	Distance From VW (ft)	Depth (feet bgs)	Initial O_2(%)	Final O_2(%)	
				Permeability Test[a/]	Long-Term System[b/]
A	17.3	17	2.8	2.0	8.8
A	17.3	32	6.0	8.0	19.8
B	12.6	16	2.3	7.4	14.2
B	12.6	32	16.8	16.8	20.4

a/ Readings taken after 12 hours of air injection.
b/ Readings taken after 20 days of air injection.

Figure 4.3
Respiration Test
Oxygen and Helium Concentrations
Site 40002, VW
Utah Test and Training Range
Hill AFB, Utah

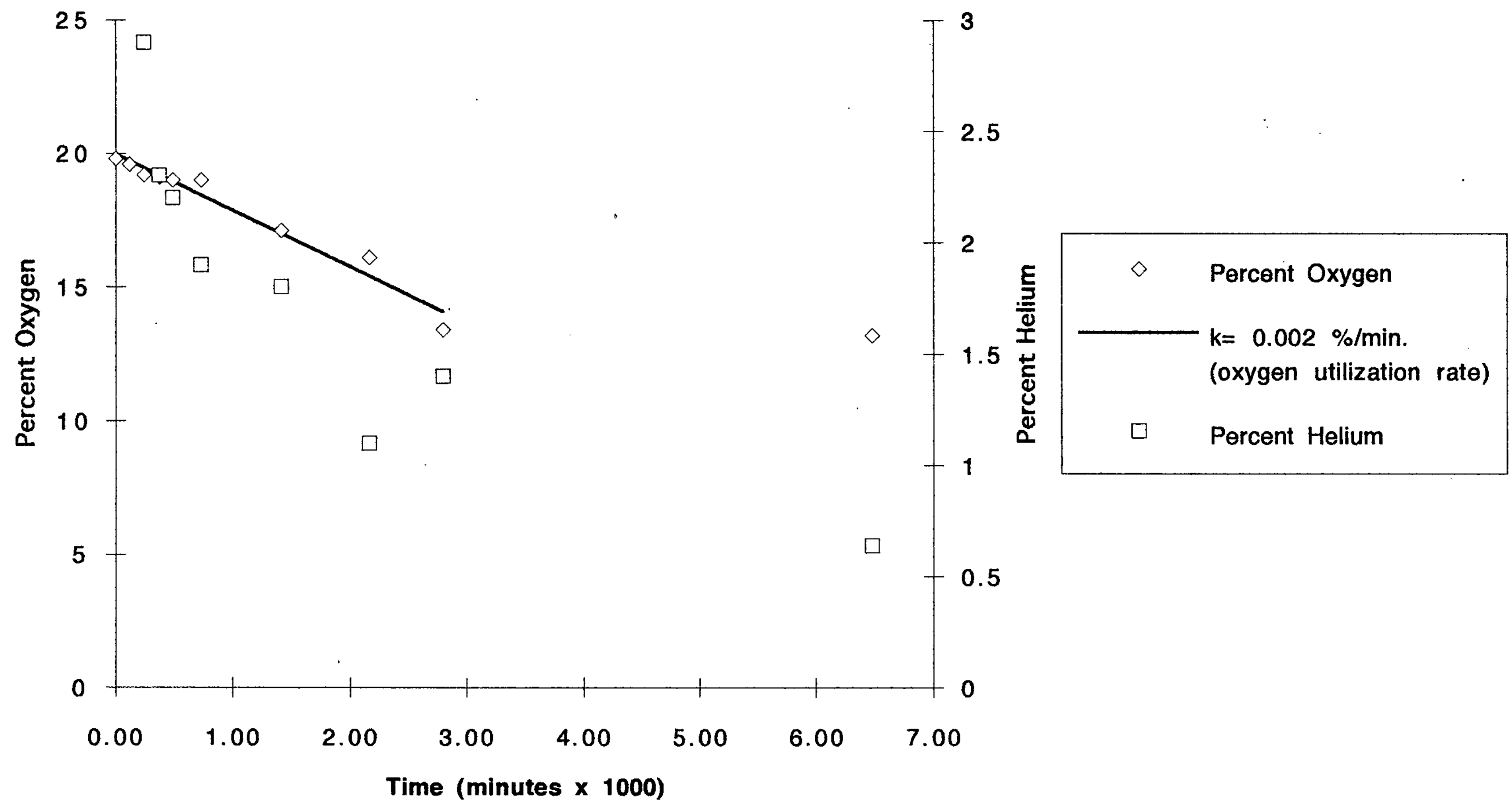


Figure 4.4
Respiration Test
Oxygen and Helium Concentrations
Site 40002, MPA-17
Utah Test and Training Range
Hill AFB, Utah

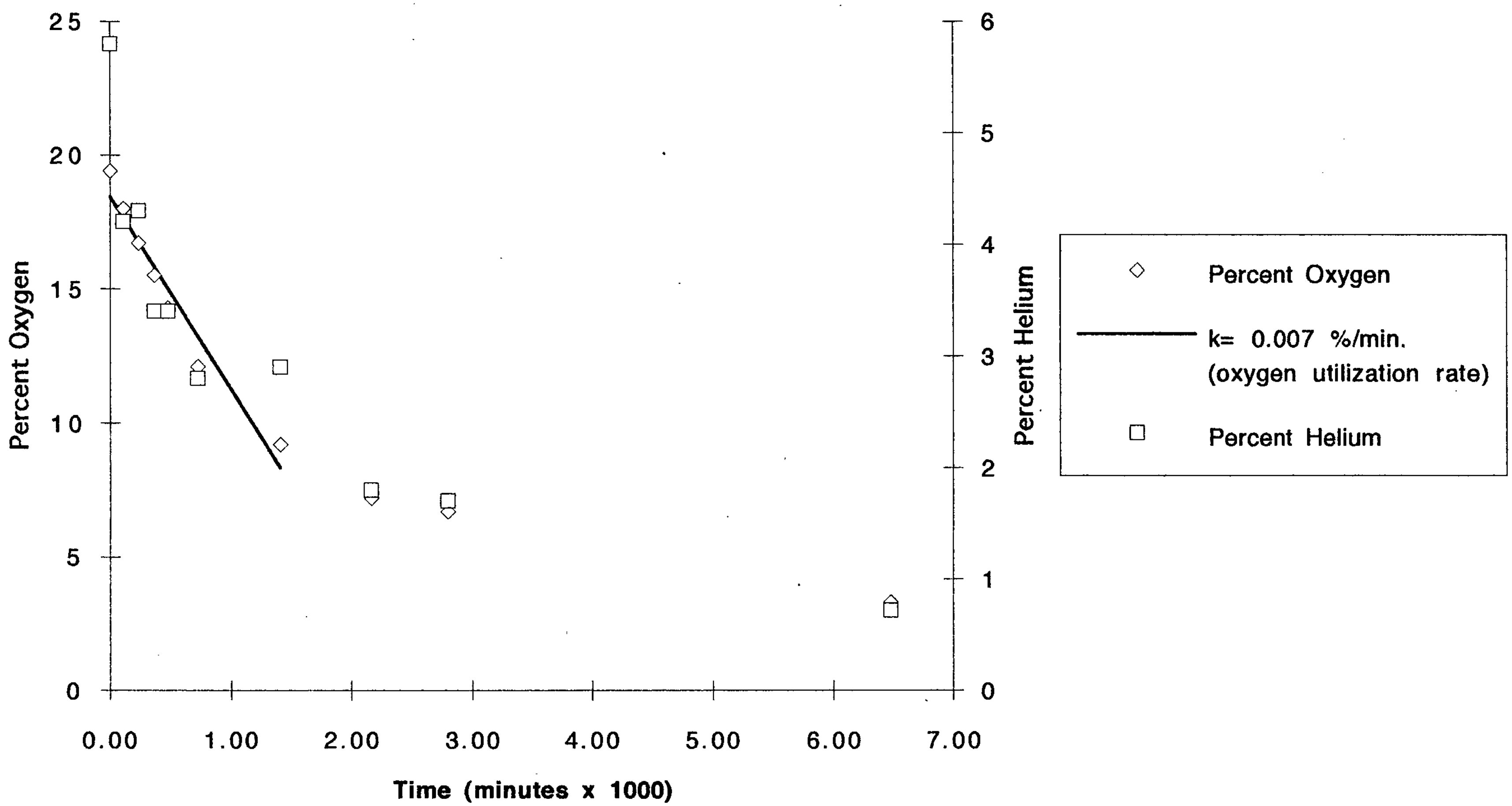


Figure 4.5
Respiration Test
Oxygen and Helium Concentrations
Site 40002, MPA-32
Utah Test and Training Range
Hill AFB, Utah

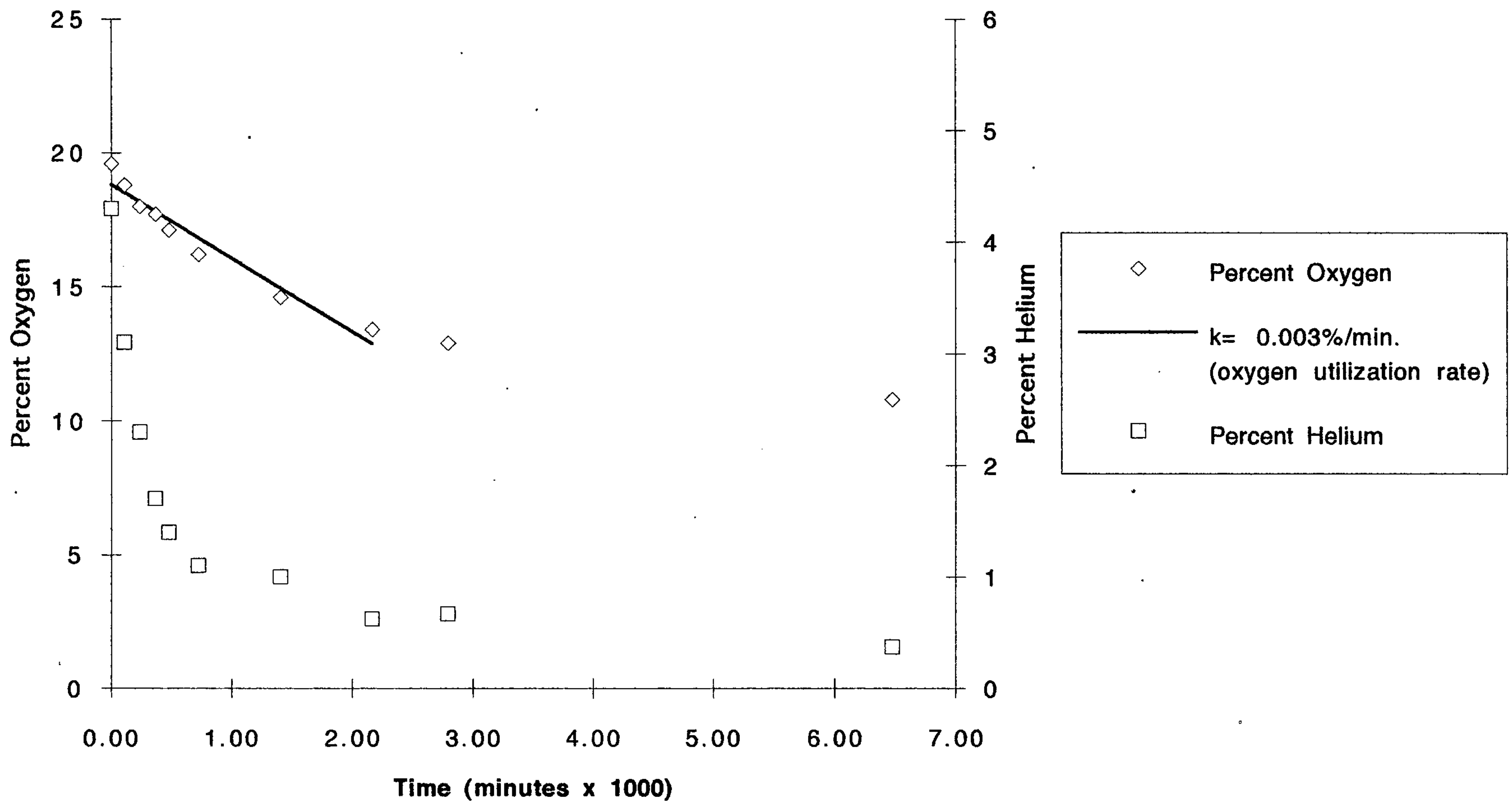


Figure 4.6
Respiration Test
Oxygen and Helium Concentrations
Site 40002, MPB-16
Utah Test and Training Range
Hill AFB, Utah

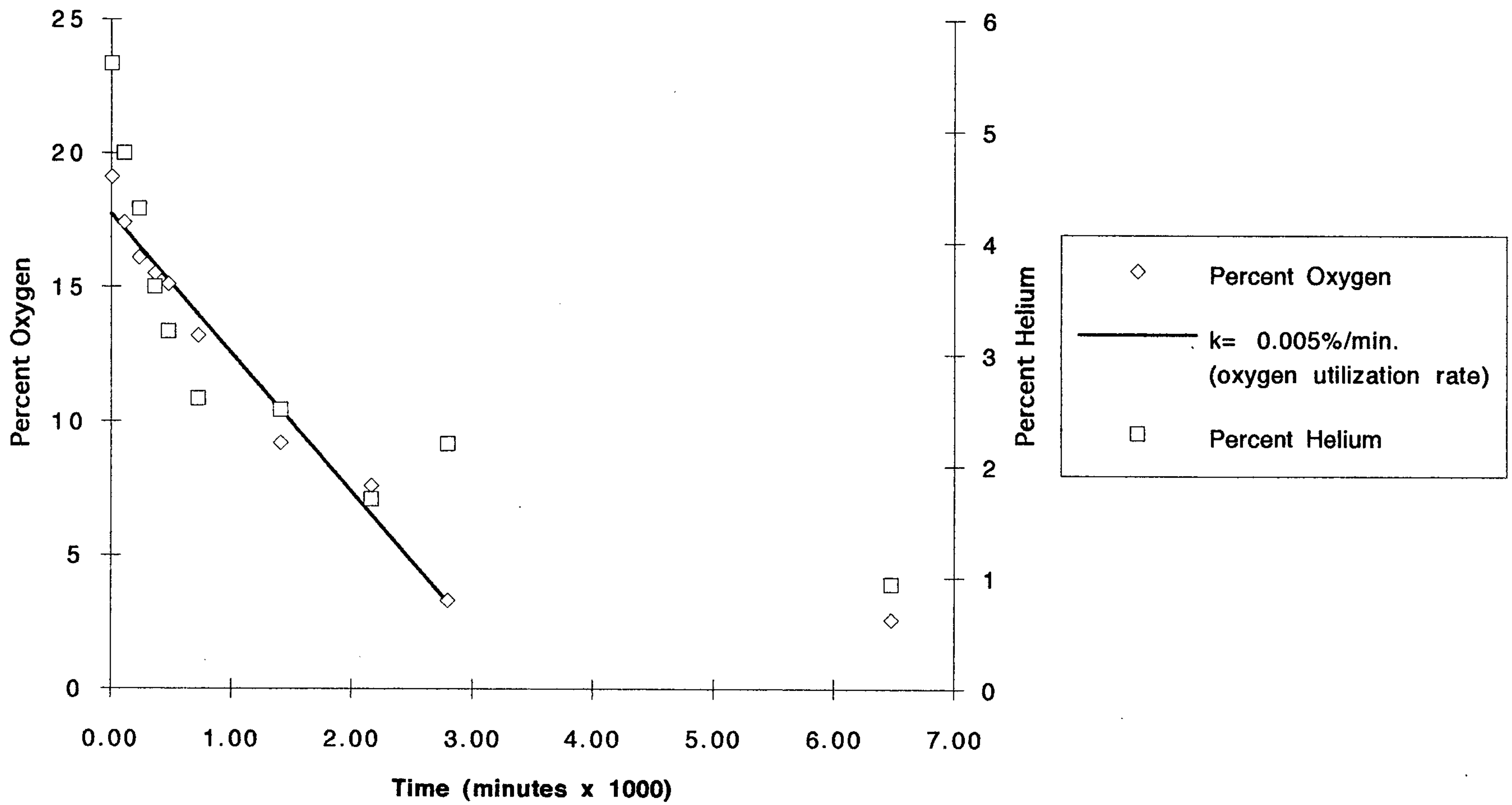


Figure 4.7
Respiration Test
Oxygen and Helium Concentrations
Site 40002, MPB-32
Utah Test and Training Range
Hill AFB, Utah

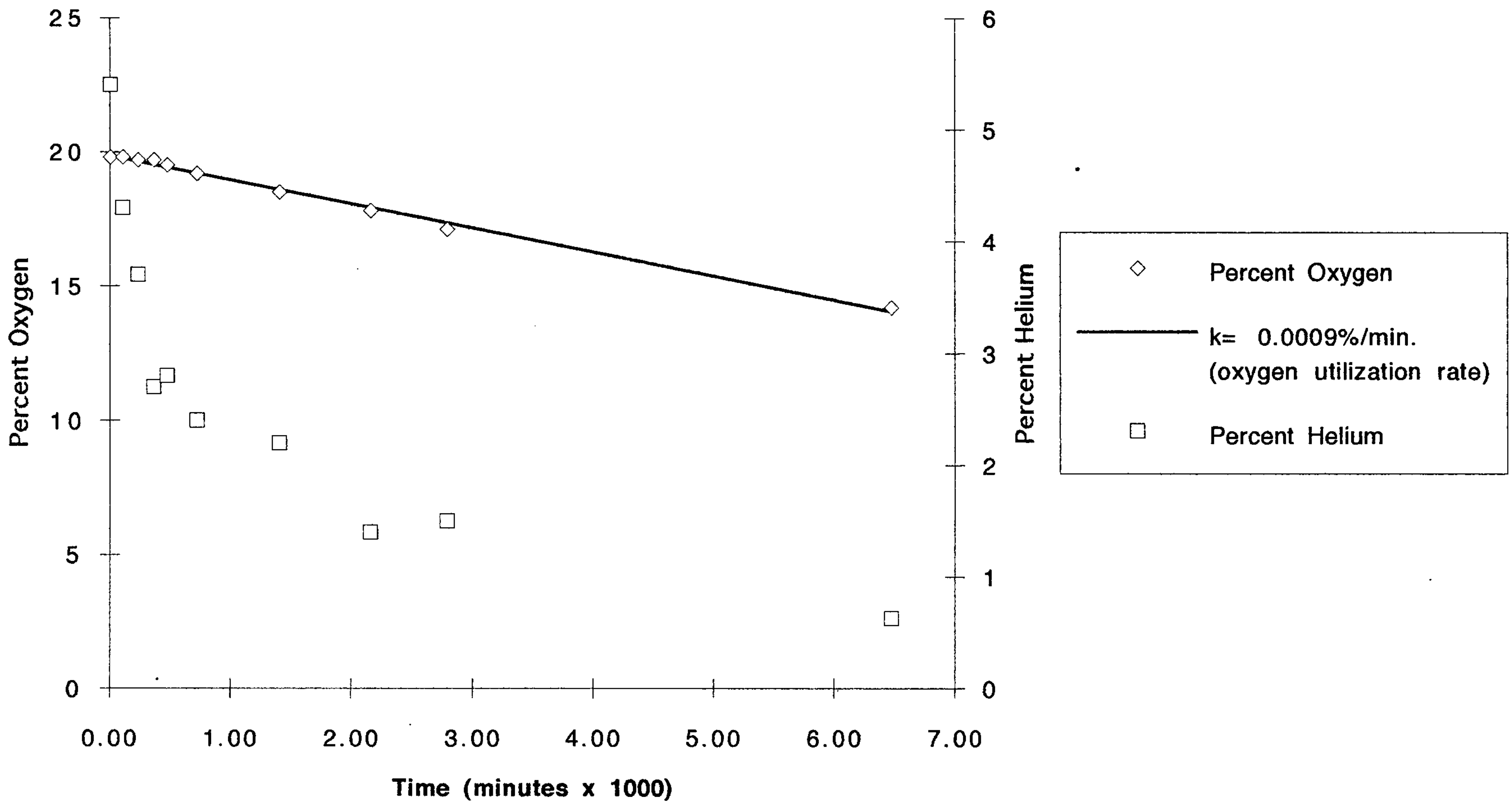


TABLE 4.4
SITE 40002
OXYGEN UTILIZATION RATES
UTAH TEST AND TRAINING RANGE
HILL AFB, UTAH

MP	O_2 Loss[a/] (%)	Test[b/] Duration (min)	O_2 Utilization[c/] Rate (%/min)
VW	6.6	6480	0.002
MPA-17	16.1	6480	0.007
MPA-32	8.8	6480	0.003
MPB-16	16.5	6480	0.005
MPB-32	5.5	6480	0.0009

a/ Actual measured oxygen loss.
b/ Elapsed time from beginning of test to time when minimum oxygen concentration was measured.
c/ Values based on linear regression (Figures 4.3 through 4.7).

measured oxygen loss can be primarily attributed to bacterial respiration rather than diffusion.

At Site 40002, an estimated 400 mg of fuel per kg of soil can be degraded each year at this site. This value is the average of the fuel consumption rates calculated for every point at which a respiration test was conducted. The MP-specific fuel consumption rates were calculated using observed oxygen utilization rates, estimated air-filled porosities, and a conservative ratio of 3.5 mg of oxygen consumed for every 1 mg of fuel biodegraded. Oxygen loss occurred linearly at slow to moderate rates, ranging from 0.0009 to 0.0072 percent per minute. The air-filled porosities, calculated for each sampling point, ranged from 0.015 to 0.117 liter of air per kg of soil.

4.5 Recommendations

Initial bioventing tests at Site 40002 indicate that oxygen has been depleted in fuel-contaminated soils, and that air injection is an effective method of stimulating aerobic fuel biodegradation. AFCEE has recommended that air injection continue on this site to determine the long-term radius of oxygen influence and the effect of time, available nutrients, and changing temperatures on fuel biodegradation rates.

A 1-HP regenerative blower has been installed on the site (Figure 4.1) for continuous air injection. In March 1994, ES will return to the site to sample and analyze the soil gas and conduct a repeat respiration test. In August 1994, a final respiration test will be conducted, and soil and soil gas samples will be collected from the site to determine the degree of remediation achieved during the first year of *in situ* treatment.

Based on the results of the first year of pilot-scale bioventing, AFCEE will recommend one of three options:

1. Upgrade and continue operation of the bioventing system for full-scale remediation of the site.
2. If final soil sampling indicates significant contaminant removal has occurred, AFCEE may recommend additional sampling to confirm that cleanup criteria have been achieved.
3. If significant difficulties or poor results are encountered during bioventing at this site, AFCEE could recommend the removal of the blower system and proper abandonment of the VWs and MPs.

5.0 REFERENCES

EA Engineering, Science, and Technology. 1991. *Subsurface Investigation Report, Tank 510.8 (Site AFLB).* Lafayette, California.

EA Engineering, Science, and Technology. 1992a. *Subsurface Investigation Report Site 388, Hill Air Force Base, Utah.* Lincoln, Nebraska. October.

EA Engineering, Science, and Technology. 1992b. *Corrective Action Plan Site 510.8 (AFLB), Hill Air Force Base, Utah.* Lincoln, Nebraska. November.

Engineering-Science, Inc. (ES). 1992. *Project Management Plan AFCEE Bioventing Pilot Tests: Appendix D-Field Sampling Plan.* Denver, Colorado. April.

Engineering-Science, Inc. (ES). 1993. *Subsurface Investigation Report, Site 40002, Hill Air Force Base, Utah.* Salt Lake City, Utah. January.

Hinchee, R.E., S.K. Ong., R.N. Miller, D.C. Downey, and R. Frandt. 1992. *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing.* Prepared for USAF Center for Environmental Excellence. May.

Hinchee R.E., and R.N. Miller. 1991. *Bioventing for In Situ Remediation of Jet Fuel.* Proceedings of Air Force Environmental Restoration Technology Symposium. San Antonio, Texas.

Montgomery Watson. 1993. Telephone and Fax Communications with Rob Herbert. Salt Lake City, Utah. August.

Radian Corporation. 1993. *Underground Storage Tank Site 1705, Abatement and Initial Site Characterization Report, Subsurface Investigation, Hill Air Force Base, Utah.* Salt Lake City, Utah. January.

APPENDIX A
SOIL BORING LOGS, WELL AND VAPOR PROBE COMPLETION DETAILS

APPENDIX A.1

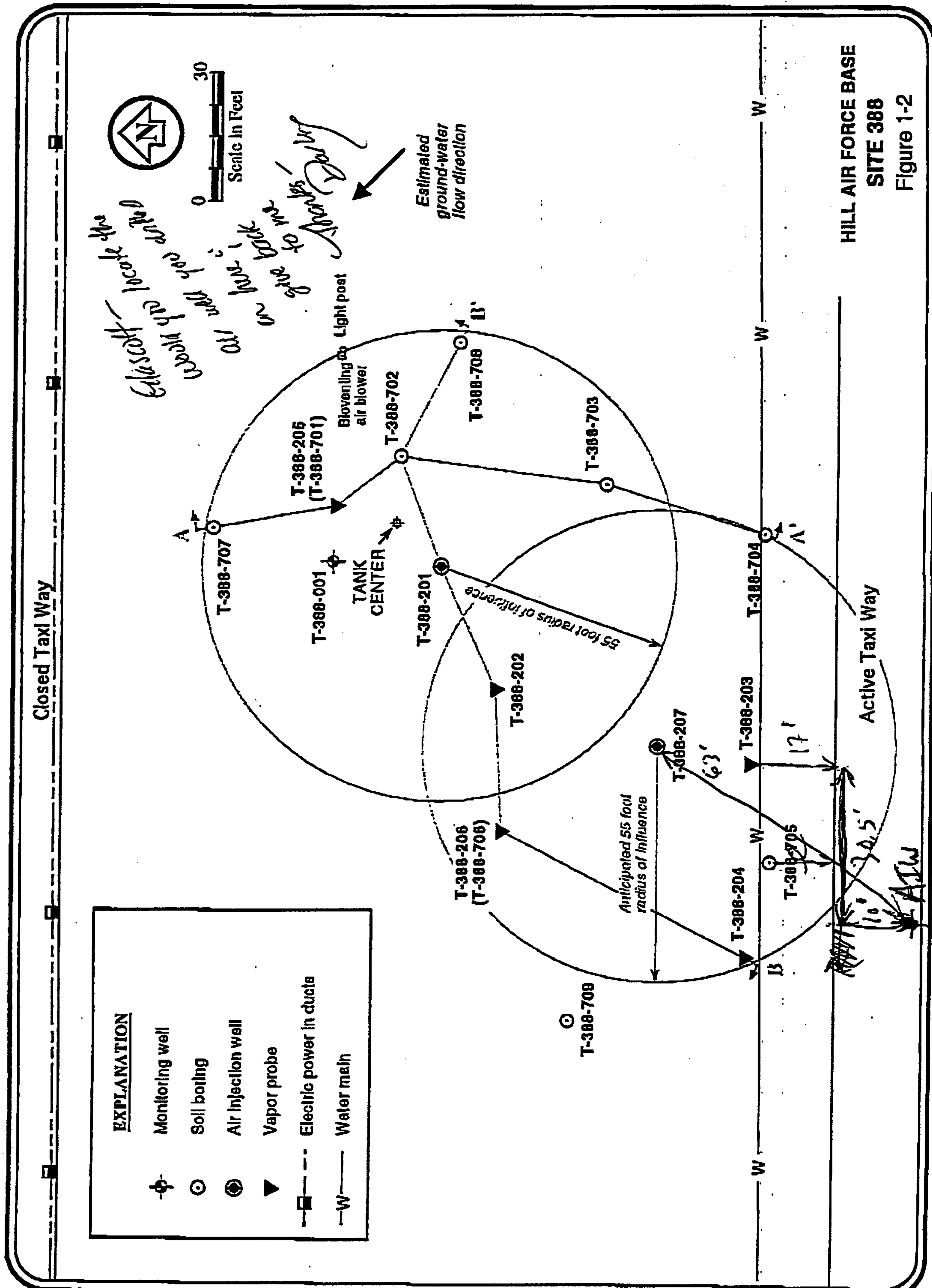
SOIL BORING LOGS, WELL AND VAPOR PROGE

COMPLETION DETAILS

SITE 388

(EA Engineering, Science, and Technology, 1992a)

(Montgomery, Watson, August 1993)



HILL AIR FORCE BASE
SITE 388
Figure 1-2

PROJECT NO. 2200.0673

SOIL VAPOR EXTRACTION WELL

Date 7-08-92

Geologist Bruce Haley

Job Number 60187.05

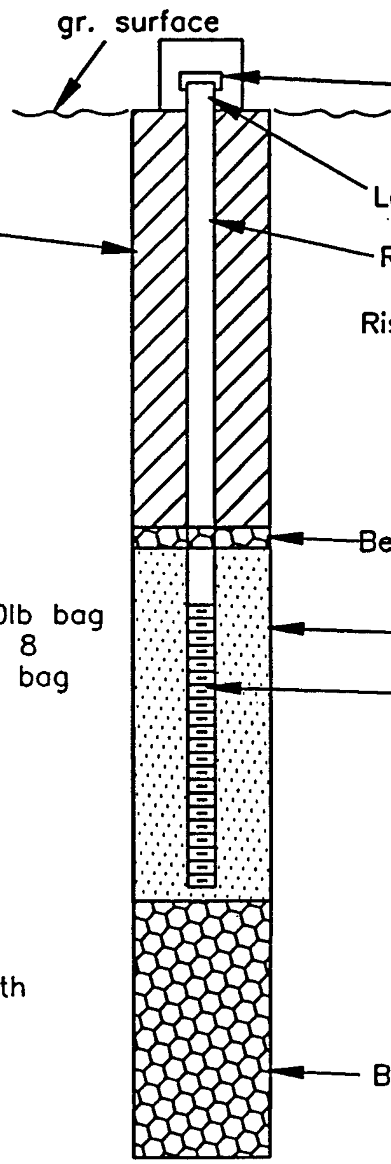
Client •Hill AFB, EMR

Well Number 388 MW-1/SVE-1

Driller PC Exploration
David Mott

Lic. # ____________

Drilling Method HSA
CME 75



Bore hole diameter
8.25 OD
4.50 ID

Sealing Material
Cement/Bentonite

Type Slurry

Proportions
97% 3%

Depth from 20 to 3

Pure Wyoming Bentonite 50lb bag
Gramusil Silica Sand Grade 8
100lb bag

Note:
All footages equal to depth below ground surface

Protective Cover (yes) or no
Type Steel

Length of well stick up 2.5 ft

Riser pipe diameter 2" schedule 80

Riser pipe length from 25 to 2.5 above surface

Bentonite Pellets/Slurry
from 22 to 20

Filter pack from 77 to 22

Screen diameter 2" schedule 80

Slot size 0.020

Screen set from 75 to 25

Total hole depth 149 backfill to 77

Bentonite Backfill

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

Figure 2-1

SOIL VAPOR PROBE INSTALLATION

Date 7-13-92 — Geologist Bruce Haley — Job Number 60187.05

Client Hill AFB, UT — Well Number 388 SB-2

Driller PC Exploration — Lic. # ______

Drilling Method HSA

Bore hole diameter 8.25 OD

Sealing Material Cement/Bentonite grout

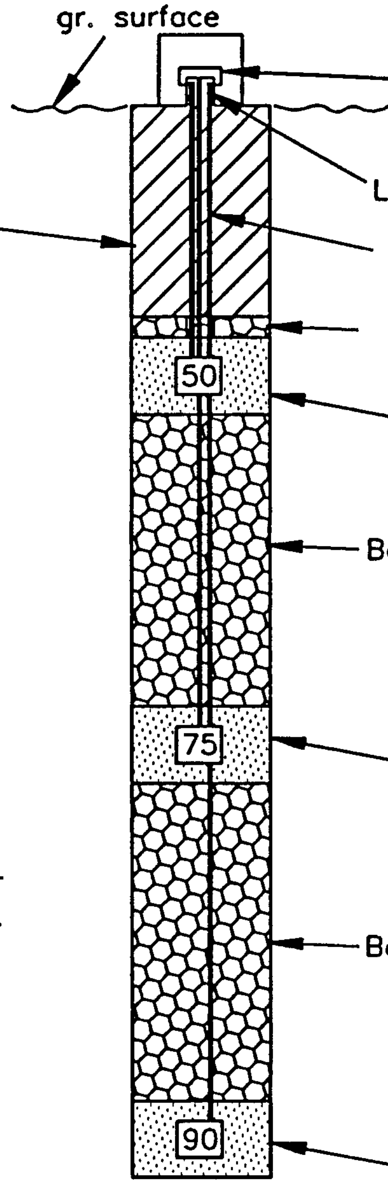
Type ______

Proportions 97%/3%

Depth from 90 to 3

Vapor Probes 1 in. ID PVC

Slot size 0.010



Protective Cover yes or no

Type Steel

Length of well stick up 2.5 ft

Tubing diameter 0.25 in

2 ft Bentonite Seal

Bentonite from 48 to 46

Filter pack from 52 to 48

Bentonite Seal

Bentonite from 73 to 52

Filter pack from 77 to 73

Bentonite Seal

Bentonite from 88 to 77

Filter pack from 90 to 88

Total hole depth 90 ft

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

Figure 2-2

SOIL VAPOR PROBE CONSTRUCTION

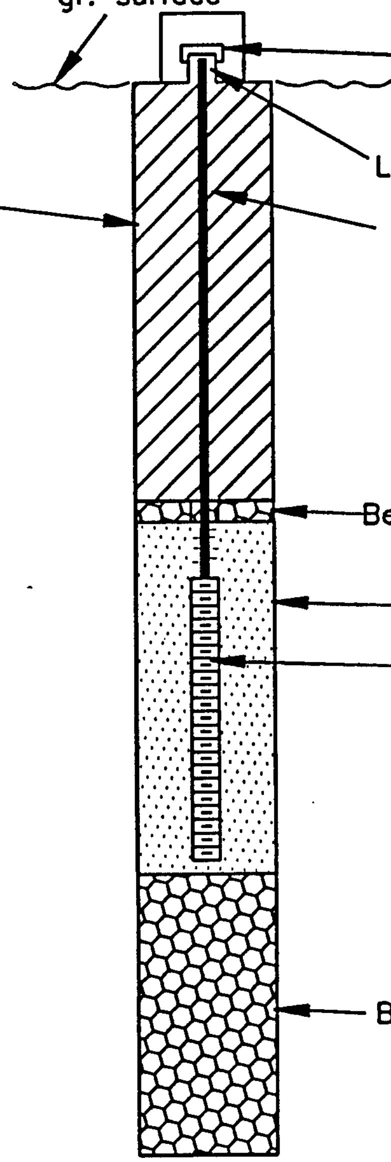
Date 7-13-92 Geologist Bruce Haley Job Number 60187.05

Client Hill AFB, UT Well Number 388 SB-5

Driller PC Exploration Lic. #

Drilling Method HSA

gr. surface



Protective Cover yes or no

Type Steel

Bore hole diameter 8.25 OD

Length of well stick up 2.5 ft

Sealing Material Cement/Bentonite grout

Tubing diameter 0.25 in

Type

Tubing length from 94 to surface

Proportions 97%/3%

Depth from 90 to 3

Bentonite Pellets/Slurry from 92 to 90

Filter pack from 96 to 92

Screen diameter 1 in.

Slot size 0.010

Screen set from 94 to 93.5

Total hole depth 120

Bentonite Backfill

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

Figure 2-3

SOIL VAPOR PROBE CONSTRUCTION

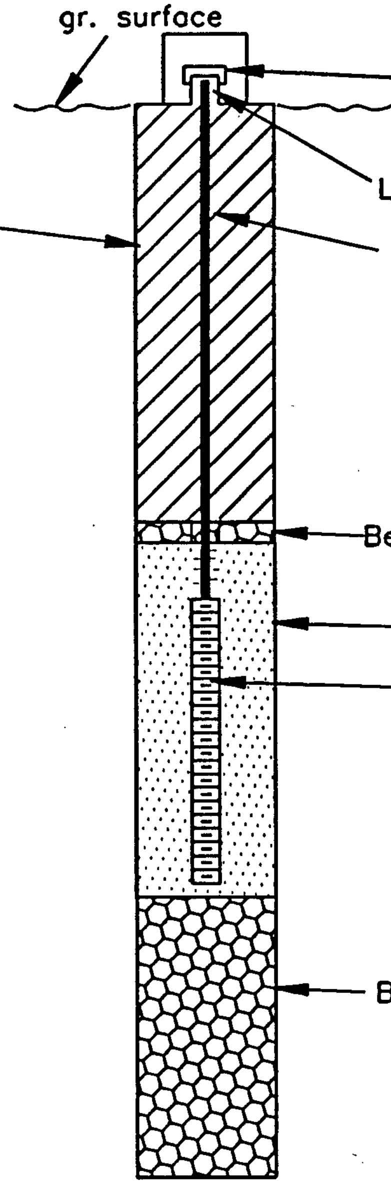
Date 7-14-92 Geologist Bruce Haley Job Number 60187.05

Client Hill AFB, UT Well Number 388 SB-6

Driller PC Exploration Lic. # ________

Drilling Method HSA

gr. surface



Protective Cover yes or no

Type Steel

Bore hole diameter
8.25 OD

Length of well stick up 2.5 ft

Sealing Material
Cement/Bentonite grout

Tubing diameter 0.25 in

Type ________

Tubing length from 94 to __ surface

Proportions
97%/3%

Depth from 90 to 3

Bentonite Pellets/Slurry
from 92 to 90

Filter pack from 96 to 92

Screen diameter 1 in.

Slot size 0.010

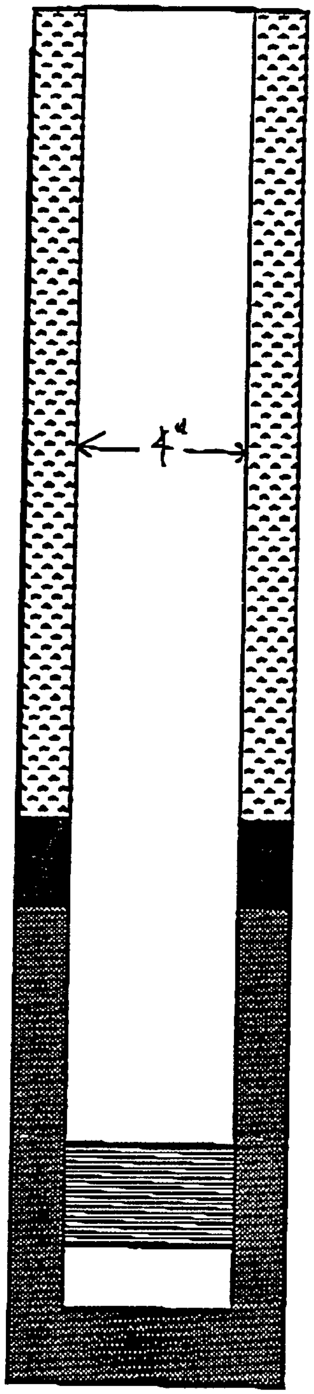
Screen set from 94 to 93.5

Total hole depth 120

Bentonite Backfill

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

Figure 2-4



(NOT TO SCALE)

MONITORING WELL NO. T-388-207

GEOLOGIST KHR

DATE CONSTRUCTION STARTED 8/3/93

DATE CONSTRUCTION COMPLETED 8/7/93

(INCLUDE ANY PROBLEMS ENCOUNTERED DURING CONSTRUCTION)

CASING SCHEDULE (INCLUDE NUMBER, TYPE AND LENGTHS OF PIPE)

55' 4" Sch 40 PVC 0.020" Slot Screen 10 cement

~~OD~~ 70' - 4" Sch 40 PVC Blank 3 p. bent.

1 - 4" " " " end cap

24 bags CSS 8/12

2 Buckets Bent pellets

0' - 3' Neat Cement/Sakrete

3' ~~4~~ - 45' CEMENT GROUT INTERVAL (CALCULATED VOLUME)

45' TOP OF BENTONITE SEAL (CALCULATED VOLUME)

50' TOP OF SAND PACK (CALCULATED VOLUME)

55' - 120' SCREENED INTERVAL

120' DEPTH OF CASING

126' BOREHOLE DEPTH

ANNULAR VOLUME:

$V = \pi H (R_1^2 - R_2^2)$

WHERE:

V = Annular Volume (ft^3)
π = 3.142
H = Length of Interval (ft)
R_1 = Borehole Radius (ft)
R_2 = Well Casing Radius (ft)

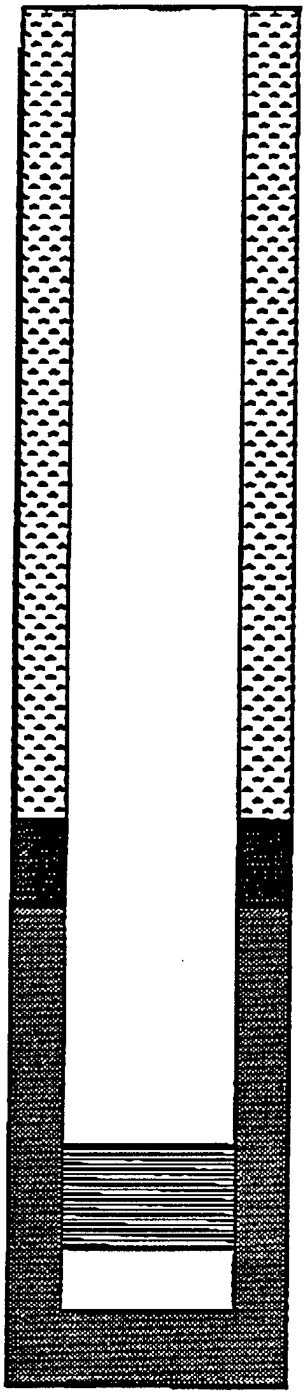
CALCULATIONS:

PROJECT NO. 2208.0341

JMM James M. Montgomery

MONITORING WELL COMPLETION SHEET
FIGURE 2-8

T-388-208 (710)



MONITORING WELL NO. ~~T-388-710/~~ AIW
GEOLOGIST RAG
DATE CONSTRUCTION STARTED 9/30/93
DATE CONSTRUCTION COMPLETED

(INCLUDE ANY PROBLEMS ENCOUNTERED DURING CONSTRUCTION)

CASING SCHEDULE (INCLUDE NUMBER, TYPE AND LENGTHS OF PIPE)

70' - 4" Sch. 40 PVC 0.020" slot screen
60' " " " " Blank
1 " " " " end cap
27 bags of CSS
28 " " bent.

CEMENT GROUT INTERVAL (CALCULATED VOLUME)

5'-55' TOP OF BENTONITE SEAL (CALCULATED VOLUME)

55' TOP OF SAND PACK (CALCULATED VOLUME)

60'-130' SCREENED INTERVAL

130' DEPTH OF CASING

150' BOREHOLE DEPTH

(NOT TO SCALE)

ANNULAR VOLUME:

$V = \pi H (R_1 - R_2)^2$

WHERE:

V = Annular Volume (ft^3)
π = 3.142
H = Length of Interval (ft)
R_1 = Borehole Radius (ft)
R_2 = Well Casing Radius (ft)

CALCULATIONS:

PROJECT NO. 2208.0301

James M. Montgomery

AIR INJECTION WELL
~~MONITORING WELL~~
COMPLETION SHEET
FIGURE 2-6

LOG OF SOIL BORING

BORING NO. 388MW-1

Geologist: Bruce Haley
Coordinates X: 0.00
Y: 0.00
Surface Elevation: 0.00
Casing Above Surface:
Reference Elevation:
Reference Description:

Aquifer:
Location: HILL AFB
Job No. 60187.05
Client: U.S. AIR FORCE
Drilling Method: 4 1/2 in. I.D. HSA

Sampling Method: SS,3 in.o.d.,2 5/8 in. I.D.,5 ft long, adv. by 4 1/2 in. I.D. HSA

Start Date: 07/07/92

Completion Date: 07/08/92

SAMP TYPE	IN. DRVN	IN. RCVD	SAMP NO.	SAMP DEPTH	BLOWS/6"	PID (headspace)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS: Local depression Grass
							0		
SS	60	22	1	4.0		2500			
							5		Moderate yellowish brown (10YR54), Dry Vf-fine sd, well sorted – (SM)
SS	24	24	2	9.0		2500			
							10		Moderate yellowish brown (10YR54), Dry Silt – (ML)
SS	24	24	3	12.0		2500			
SS	60	27	4	14.0		2500			Pale yellowish brown (10YR62), Dry Vf-fine sd, well sorted – (SM)
							15		
SS	60	16	5	19.0		2500			Pale yellowish brown (10YR62), Dry Med sd, 10-20% gravel – (GM)
							20		

SAMPLER TYPE
SS – DRIVEN SPLIT SPOON
SH – PRESSED SHELBY TUBE
OST – OSTENBURG PISTON SAMPLER
DEN – DENISON CORE BARREL SAMPLER
SPT – STANDARD PENETRATION TEST (ASTM D 1586-84)
SHV – STAINLESS STEEL SHOVEL
NS – NO SAMPLE

GROUND-WATER DEPTH BELOW GRADE
AT COMPLETION not encountered
AFTER HRS. 0.00 FT.
AFTER 24 HRS. FT.

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.

LOG OF SOIL BORING

BORING NO. 388MW-1

SAMP TYPE	IN. DRVN	IN. RCVD	SAMP NO.	SAMP DEPTH	BLOWS/6"	PID (headspace)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS:
							20		
SS	60	16	6	24.0		2500			
							25		
SS	60	16	7	29.0		2500			
							30		
SS	24	24	8	34.0		2500			Pale yellowish brown (10YR62), Dry F-med sd, poor sorting - (SM)
							35		
SS	24	24	9	36.0		2500			
SS	24	24	10	39.0	54 TOTAL	2500			
							40		
SS	24	24	11	41.0	54 TOTAL	2500			
SS	24	24	12	44.0	140 TOTAL	2500			
							45		Pale yellowish brown (10YR62), Dry F-med sd, 10% gravel - (GM)
SS	24	24	13	46.0		2500			
SS	24	24	14	48.5		2500			Pale yellowish brown (10YR62), Dry Fine-med sd, poor sorting - (SM)
							50		

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LOG OF SOIL BORING

BORING NO. 388MW-1

SAMP TYPE	IN. DRVN	IN. RCVD	SAMP NO.	SAMP DEPTH	BLOWS/6"	PID (headspace)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS:
							50		
SS	24	24	15	51.0	>100	2500			
SS	24	24	16	53.5	100 TOTAL	2500			
							55		Moderate yellowish brown 10 YR 5/4 F-Med Sd, (SM)
SS	24	24	17	56.0		2500			
SS	60	38	18	58.5		2500			
							60		
SS	60	39	19	64.0		2500			
							65		
SS	60	42	20	69.0		342			
							70		
SS	60	37	21	74.0		10			Moderate yellowish brown 10 YR 5/4 F-Med Sd, (SM)
							75		
SS	60	27	22	79.0		50			
							80		

LOG OF SOIL BORING

BORING NO. 388MW-1

SAMP TYPE	IN. DRVN	IN. RCVD	SAMP NO.	SAMP DEPTH	BLOWS/6"	PID (headspace)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS:
							80		
									Pale yellowish brown (10YR62), Dry F-med sd, 10-15% gravel - (GM)
SS	60	42	23	84.0		90			
							85		
									Pale yellowish brown (10YR62), Dry Fine- med sd, poor sorting - (SM)
SS	60	42	24	89.0		182			
							90		
SS	60	42	25	94.0		17			
							95		
									Dark yellowish brown (10YR66), Sl moist Fine sd, mod.well sorted - (SM)
SS	60	36	26	99.0		5			
							100		
SS	60	45	27	104.0		2			
							105		Moderate yellowish brown (10YR54), Dry F-med sd, thin layers iron stains - (SM)
SS	60	43	28	109.0		4			
							110		

LOG OF SOIL BORING

BORING NO. 388MW-1

SAMP TYPE	IN. DRVN	IN. RCVD	SAMP NO.	SAMP DEPTH	BLOWS/6"	PID (headspace)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS:
							110		
SS	60	38	29	114.0		1			
							115		
SS	60	38	30	119.0		3			
							120		
SS	60	36	31	124.0		3			
							125		
									Moderate yellowish brown (10YR54), Dry F-med sd, thin layers silt mixed – (SM)
SS	60	50	32	129.0		3			
							130		
SS	60	45	33	134.0		3			Moderate yellowish brown (10YR54), Dry Fine sd, thin layers silt mixed – (SM)
							135		
SS	60	46	34	139.0		8			
							140		

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LOG OF SOIL BORING

BORING NO. 388MW-1

SAMP TYPE	IN. DRVN	IN. RCVD	SAMP NO.	SAMP DEPTH	BLOWS/6"	PID (headspace)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS:
							140		
SS	60	42	35	144		N/S			Moderate yellowish brown 10 YR 5/4 Fine SD, (SM) Dry
							145		
							150		Total Depth 150 ft.
							155		
							160		
							165		
							170		

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.

LOG OF SOIL BORING

BORING NO. 388SB-2

Geologist: Bruce Haley
Coordinates X: 0.00
Y: 0.00
Surface Elevation: 0.00
Casing Above Surface:
Reference Elevation:
Reference Description:

Aquifer:
Location: HILL AFB
Job No. 60187.05
Client: U.S. AIR FORCE
Drilling Method: 4 1/2 in. I.D. HSA

Sampling Method: SS,3 in.o.d.,2 5/8 in.I.D.,5 ft long, adv. by 4 1/2 in. I.D. HSA

Start Date: 07/09/92

Completion Date: 07/09/92

SAMP TYPE	IN. DRVN	IN. RCVD	SAMP NO.	SAMP DEPTH	BLOWS/6"	PID (headspace)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS: Local depression Grass
SS	24	24	1	0.0		N/S	0		
SS	24	24	2	2.0		7			Dark yellowish brown (10YR66), Dry Vf-silty sd, - (SM)
SS	24	24	3	4.0		N/S			
							5		
SS	24	24	4	6.0		6			
SS	24	24	5	8.0		N/S			
SS	24	24	6	10.0		3	10		Dark yellowish brown (10YR66), Dry F-Med SD
SS	24	24	7	12.0		N/S			
SS	36	32	8	14.0		3			
							15		
SS	24	0	9	17.0		N/S			Moderate yellow brown (10YR54), Dry F-c sd, 10% gravel - (GM)
SS	60	14	10	19.0		1			
							20		

SAMPLER TYPE
SS – DRIVEN SPLIT SPOON
SH – PRESSED SHELBY TUBE
OST – OSTENBURG PISTON SAMPLER
DEN – DENISON CORE BARREL SAMPLER
SPT – STANDARD PENETRATION TEST (ASTM D 1586-84)
SHV – STAINLESS STEEL SHOVEL
NS – NO SAMPLE

GROUND-WATER DEPTH BELOW GRADE
AT COMPLETION not encountered
AFTER HRS. 0.00 FT.
AFTER 24 HRS. FT.

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.

LOG OF SOIL BORING

BORING NO. 388SB-2

SAMP TYPE	IN. DRVN	IN. RCVD	SAMP NO.	SAMP DEPTH	BLOWS/6"	PID (headspace)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS:
							20		
SS	60	30	11	24.0		5			
							25		
SS	60	14	12	29.0		3			
							30		
SS	60	39	13	34.0		3			
							35		Moderate yellowish brown (10YR54). Dry F-med sd, poor sorting - (SM)
SS	60	36	14	39.0		4			
							40		
SS	60	39	15	44.0		97			
							45		
SS	60	32	16	49.0		43			Pale yellowish brown (10YR62). Dry F-med sd, poor sorting - (SM)
							50		

LOG OF SOIL BORING

BORING NO. 388SB-2

SAMP TYPE	IN. DRVN	IN. RCVD	SAMP NO.	SAMP DEPTH	BLOWS/6"	PID (headspace)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS:
							50		
SS	60	33	17	54.0		2500			
							55		
						HNu			
SS	60	37	18	59.0		320			Pale Yellowish Brown 10 YR 6/2 F-Med SD, (SM) Thin layers Iron Stains.
							60		
SS	60	32	19	64.0		320			
							65		
SS	60	42	20	69.0		300			
							70		
SS	60	34	21	74.0		300			
							75		
SS	60	47	22	79.0		10			
							80		

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LOG OF SOIL BORING

BORING NO. 388SB-2

SAMP TYPE	IN. DRVN	IN. RCVD	SAMP NO.	SAMP DEPTH	BLOWS/6"	PID (headspace)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS:
							80		
									Pale Yellowish Brown 10 YR 6/2
SS	60	21	23	84		24			
							85		
							90		Total Depth 90 ft
							95		
							100		
							105		
							110		

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.

LOG OF SOIL BORING

BORING NO. 388SB-5

Geologist: Bruce Haley
Coordinates X: 0.00
Y: 0.00
Surface Elevation: 0.00
Casing Above Surface:
Reference Elevation:
Reference Description:

Aquifer:
Location: HILL AFB
Job No. 60187.05
Client: U.S. AIR FORCE
Drilling Method: 4 1/2 in. I.D. HSA

Sampling Method: SS,3 in.o.d.,2 5/8 in. I.D.,5 ft long, adv. by 4 1/2 in. I.D. HSA

Start Date: 07/13/92

Completion Date: 07/13/92

SAMP TYPE	IN. DRVN	IN. RCVD	SAMP NO.	SAMP DEPTH	BLOWS/6"	PID (headspace)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS: Local depression Grass
							0		
							5		Drill out to 54 ft to begin sampling.
							10		
							15		
							20		

SAMPLER TYPE
SS – DRIVEN SPLIT SPOON
SH – PRESSED SHELBY TUBE
OST – OSTENBURG PISTON SAMPLER
DEN – DENISON CORE BARREL SAMPLER
SPT – STANDARD PENETRATION TEST (ASTM D 1586-84)
SHV – STAINLESS STEEL SHOVEL
NS – NO SAMPLE

GROUND-WATER DEPTH BELOW GRADE
AT COMPLETION not encountered
AFTER HRS. 0.00 FT.
AFTER 24 HRS. FT.

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.

LOG OF SOIL BORING

BORING NO. 388SB-5

SAMP TYPE	IN. DRVN	IN. RCVD	SAMP NO.	SAMP DEPTH	BLOWS/6"	PID (headspace)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS:
							20		
							25		
							30		
							35		
							40		
							45		
							50		

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.

LOG OF SOIL BORING

BORING NO. 388SB-5

SAMP TYPE	IN. DRVN	IN. RCVD	SAMP NO.	SAMP DEPTH	BLOWS/6"	PID (headspace)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS:
							50		
SS	60	36	1	54.0		1100			
							55		
SS	60	38	2	59.0		4			Moderate yellowish brown (10YR54), Dry F-med sd, thin layers iron stains - (SM)
							60		
SS	60	32	3	64.0		1500			
							65		
SS	60	43	4	69.0		2500			Pale yellowish brown (10YR62), Dry F-med sd, poor sorting - (SM)
							70		
									Moderate yellowish brown (10YR54), Dry Silt - (ML)
SS	60	6	5	74.0		NO S			
							75		
									Pale yellowish brown (10YR62), Dry F-med sd, thin layers iron stains - (SM)
SS	60	48	6	79.0		2500			
							80		

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.

LOG OF SOIL BORING

BORING NO. 388SB-5

SAMP TYPE	IN. DRVN	IN. RCVD	SAMP NO.	SAMP DEPTH	BLOWS/6"	PID (headspace)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS:
							80		
SS	60	43	7	84.0		2500			
							85		
SS	60	38	8	89.0		2500			
							90		
SS	60	38	9	94.0		2500			
							95		
									Moderate yellowish brown (10YR54), Dry Vf-fine sd, - (SM)
SS	60	36	10	99.0		2500			Pale yellowish brown (10YR62), Dry F-med sd - (SM)
							100		
SS	60	40	11	104.0		2500			Pale yellowish brown (10YR62), Dry F-med sd, 15% gravel - (GM)
							105		
SS	60	42	12	109.0		1242			Pale yellowish brown (10YR62), Dry F-med sd, poor sorting - (SM)
							110		

LOG OF SOIL BORING

BORING NO. 388SB-5

SAMP TYPE	IN. DRVN	IN. RCVD	SAMP NO.	SAMP DEPTH	BLOWS/6"	PID (headspace)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS:
							110		Moderate yellowish brown (10YR54). Dry Silt, w/vf sd – (ML)
SS	60	36	13	114.0		425	115		
									Moderate yellowish brown (10YR54). Dry F–med sd – (SM)
									Total Depth 119
							120		
							125		
							130		
							135		
							140		

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LOG OF SOIL BORING

BORING NO. 388SB-6

Geologist: Bruce Haley
Coordinates X: 0.00
Y: 0.00
Surface Elevation: 0.00
Casing Above Surface:
Reference Elevation:
Reference Description:

Aquifer:
Location: HILL AFB
Job No. 60187.05
Client: U.S. AIR FORCE
Drilling Method: 4 1/2 in. I.D. HSA

Sampling Method: SS,3 in.o.d.,2 5/8 in. I.D.,5 ft long, adv. by 4 1/2 in. I.D. HSA

Start Date: 07/13/92

Completion Date: 07/14/92

SAMP TYPE	IN. DRVN	IN. RCVD	SAMP NO.	SAMP DEPTH	BLOWS/6"	PID (headspace)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS: Local depression Grass
							0		
							5		Drillout to 79 ft to begin first samples.
							10		
							15		
							20		

SAMPLER TYPE
SS – DRIVEN SPLIT SPOON
SH – PRESSED SHELBY TUBE
OST – OSTENBURG PISTON SAMPLER
DEN – DENISON CORE BARREL SAMPLER
SPT – STANDARD PENETRATION TEST (ASTM D 1586-84)
SHV – STAINLESS STEEL SHOVEL
NS – NO SAMPLE

GROUND-WATER DEPTH BELOW GRADE
AT COMPLETION not encountered
AFTER HRS. 0.00 FT.
AFTER 24 HRS. FT.

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.

LOG OF SOIL BORING

BORING NO. 388SB-6

SAMP TYPE	IN. DRVN	IN. RCVD	SAMP NO.	SAMP DEPTH	BLOWS/6"	PID (headspace)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS:
							20		
							25		
							30		
							35		
							40		
							45		
							50		

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.

LOG OF SOIL BORING

BORING NO. 388SB-6

SAMP TYPE	IN. DRVN	IN. RCVD	SAMP NO.	SAMP DEPTH	BLOWS/6"	PID (headspace)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS:
							50		
							55		
							60		
							65		
							70		
							75		
SS	60	37	1	79.0		120			Moderate yellowish brown (10YR54), Dry F-med sd, stong odor - (SM)
							80		

LOG OF SOIL BORING

BORING NO. 388SB-6

SAMP TYPE	IN. DRVN	IN. RCVD	SAMP NO.	SAMP DEPTH	BLOWS/6"	PID (headspace)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS:
							80		
SS	60	42	2	84.0		120			
							85		
SS	60	40	3	89.0		240			
							90		
SS	60	15	4	94.0		648			
							95		Pale yellowish brown (10YR62), Dry F-med sd, thin layers iron stains – (SM)
SS	60	48	5	99.0		263			
							100		
SS	60	44	6	104.0		398			
							105		Moderate yellowish brown (10YR54), Dry F-med sd, thin layers iron stains – (SM)
SS	60	38	7	109.0		297			
							110		

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LOG OF SOIL BORING

BORING NO. 388SB-6

SAMP TYPE	IN. DRVN	IN. RCVD	SAMP NO.	SAMP DEPTH	BLOWS/6"	PID (headspace)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS:
							110		
SS	60	40	8	114	•	24	115		Moderate yellowish Brown 10 YR 5/4 F-Med SD, (SM), dry, thin layers iron stains.
									Total Depth 119 ft
							120		
							125		
							130		
							135		
							140		

APPENDIX A.2

SOIL BORING LOGS, WELL AND VAPOR PROBE COMPLETION DETAILS

SITE 510.8

(EA Engineering, Science, and Technology, 1992b)

GEOLOGIC BORING LOG

BORING NO.:	MPA	CONTRACTOR:	PC Exploration	DATE SPUD:	8-9-93
CLIENT:	AFCEE	RIG TYPE:	Acker Soil Max	DATE CMPL:	8-9-93
JOB NO.:	DE268.09.04	DRLG METHOD:	HSA	ELEVATION:	
LOCATION:	Site 510.8, Hill AFB, UT	BORING DIA.:	8" OD	TEMP.:	90°F
GEOLOGIST:	John Ratz	DRLG FLUID	None	WEATHER:	sunny, calm

COMMENTS:

Elev. (ft.)	Depth (ft.)	Profile	USCS	Geologic Description	Sample No.	Sample Depth(ft)	Sample Type	Penet. Res.	Remarks TIP = Bkgrnd/Reading (ppm)
	1		GW	GRAVEL, subangular, 1/4" to 2" dia w sm sand and silt.					
			SW	SAND, reddish brown, vf-m, well-graded w sm angular gravel 1/2" dia and tr silt. No odor, moist.	1 0845	18" recovery	D	12-5-2	no HC rdg taken
	5								
				8.5'-10' SAND, reddish brown, vf-m, well graded w tr silt. No odor, moist.	2 0850	18" recovery	D	11-6-6	HC = 61 ppmv
	10								
	15								
				18.5'-20' SAND, reddish brown, vf-c, moist, no odor. Some small clay "nodules" to 1/2" dia.	3 0915	18" recovery	D	16-22-29	HC = 62 ppmv
	20								
	25								
			SW	28.5'-30' SAND, reddish brown, vf-m, w sm rounded gravel 1/2" in dia. Clay lens at 29' bgs, moist, hydrocarbon odor	4 1000	18" recovery	D	8-9-12	HC = 360 ppmv
	30								
	35								

sl - slight	v - very	f - fine	**SAMPLE TYPE**	
tr - trace	lt - light	m - medium	D - DRIVE	D Core recovery
sm - some	dk - dark	c - coarse	C - CORE	
& - and	bf - buff	BH - Bore Hole	G - GRAB	Core lost
@ - at	brn - brown	SAA - Same As Above		
w - with	blk - black	veg - Vegetation		Water level drilled

GEOLOGIC BORING LOG

BORING NO.:	MPA	CONTRACTOR:	PC Exploration	DATE SPUD:	8-9-93
CLIENT:	AFCEE	RIG TYPE:	Acker Soil Max	DATE CMPL:	8-9-93
JOB NO.:	DE268.09.04	DRLG METHOD:	HSA	ELEVATION:	
LOCATION:	Site 510.8 Hill AFB UT	BORING DIA.:	8" OD	TEMP.:	90°F
GEOLOGIST:	John Ratz	DRLG FLUID	None	WEATHER:	sunny, calm
COMMENTS:					

Elev. (ft.)	Depth (ft.)	Pro-file	USCS	Geologic Description	Sample No.	Sample Depth(ft)	Sample Type	Penet. Res.	Remarks TIP = Bkgrnd/Reading (ppm)
	35		SW						
				38.5'-40' SAND, SAA, with no gravel or clay lenses, tr clay.	5	18"		7-24-	HC = 440 ppm
	40			Hydrocarbon odor present - "fingers" of contamination.	1030	recovery	D	34	
	45								
					6	10"		35-50	HC = 620 ppm
	50			SAND, SAA, very strong hydrocarbon odor.	1115	recovery	D	for 10"	lab sample
									TD = 51' bgs
	55								
	60								
	65								
	70								

sl - slight
tr - trace
sm - some
& - and
@ - at
w - with

v - very
lt - light
dk - dark
bf - buff
brn - brown
blk - black

f - fine
m - medium
c - coarse
BH - Bore Hole
SAA - Same As Above
veg - Vegetation

SAMPLE TYPE
D - DRIVE
C - CORE
G - GRAB

D Core recovery
Core lost
Water level drilled

GEOLOGIC BORING LOG

BORING NO.:	MPB	CONTRACTOR:	PC Exploration	DATE SPUD:	8-3-93
CLIENT:	AFCEE	RIG TYPE:	Acker Soil Max	DATE CMPL:	8-3-93
JOB NO.:	DE268.09.04	DRLG METHOD:	HSA	ELEVATION:	
LOCATION:	Site 510.8, Hill AFB UT	BORING DIA.:	12" OD	TEMP.:	90°F
GEOLOGIST:	John Rotz	DRLG FLUID	None	WEATHER:	Sunny, calm

COMMENTS: Original borehole was 8" dia; over-drilled using 12" OD auger to recover auger flights lost in the borehole.

Elev. (ft.)	Depth (ft.)	Profile	US CS	Geologic Description	Sample No.	Sample Depth(ft)	Sample Type	Penet. Res.	Remarks TIP = Bkgrnd/Reading (ppm)
	1		GW	2" of asphalt at the surface, 2"-3' well-rounded gravel, 1/4" to 1" dia w sm silt and sand, dry, no odor					
	5		SW	3'-5' SAND, reddish brown, well-graded vf-f, sm c sand and well rounded pea gravel to 1/4" dia, tr silt, sl moist					
				5'-8.5' SAND, reddish brown, well-graded vf-f, tr silt, sl moist, no odor.					
	10			8.5'-10' SAND, reddish brown, well-graded vf-f, tr gravel, well rounded 1/4" to 1/2" dia, sl moist	1 1200	18" recovery	D	13-15-15	HC = 91 ppmv sl petroleum odor
				10'-18.5' SAND, reddish brown, well-graded vf-m, tr coarse sand, sl moist, no odor					
	15								
	20		SP	18.5'-20' SAND reddish brown, f-m, poorly graded, tr gravel 1/4" dia, sl moist, no odor	2 1220	18" recovery	D	11-23-29	HC = 97 ppmv no odor
				20'-28.5' SAND, SAA					
	25								
	30		SW	28.5'-30' SAND, reddish brown, vf-f, well-graded, sl moist, no odor. Clay lens 2" thick at 30'	3 1245	18" recovery	D	20-31-29	HC = 96 ppmv no odor
			SP	30'-38.5' SAND, reddish brown, vf-c, poorly graded, sl moist, no odor. Tr gravel well rounded to 1" dia.					
	35								

sl - slight	v - very	f - fine	SAMPLE TYPE			
tr - trace	lt - light	m - medium	D - DRIVE	D	Core recovery	
sm - some	dk - dark	c - coarse	C - CORE			
& - and	bf - buff	BH - Bore Hole	G - GRAB		Core lost	
@ - at	brn - brown	SAA - Same As Above				
w - with	blk - black	veg - Vegetation		Water level drilled		

GEOLOGIC BORING LOG

BORING NO.:	MPB	CONTRACTOR:	PC Exploration	DATE SPUD:	8-3-93
CLIENT:	AFCEE	RIG TYPE:	Acker Soil Max	DATE CMPL:	8-3-93
JOB NO.:	DE268.09.04	DRLG METHOD:	HSA	ELEVATION:	
LOCATION:	Site 510.8, Hill AFB, UT	BORING DIA.:	12" OD	TEMP.:	90°F
GEOLOGIST:	John Ratz	DRLG FLUID	None	WEATHER:	sunny, calm
COMMENTS:					

Elev. (ft.)	Depth (ft.)	Profile	USCS	Geologic Description	Sample No.	Sample Depth(ft)	Sample Type	Penet. Res.	Remarks TIP = Bkgrnd/Reading (ppm)
	~~0~~ 35		SP	SAND, SAA					
				38.5'-40' SAND, reddish brown, vf-f, well graded, sl moist,	4	18"		9-35-	HC=155 ppmv
	~~5~~ 40		SW	tr silt, no odor.	1320	recovery	D	50	lab sample 38.5' to 39.2'
				40'-48.5' SAND, SAA					
	~~10~~ 45								
				48.5'-50' SAND, reddish brown, vf-f, well graded, sl moist,	5	11"		26-50	HC=130 ppmv
	~~15~~ 50			tr silt, no odor	1545	recovery	D	for 11"	
									TD=51' bgs
	~~20~~ 55								
	~~25~~ 60								
	~~30~~ 65								
	~~35~~ 70								

sl - slight
tr - trace
sm - some
& - and
@ - at
w - with

v - very
lt - light
dk - dark
bf - buff
brn - brown
blk - black

f - fine
m - medium
c - coarse
BH - Bore Hole
SAA - Same As Above
veg - Vegetation

SAMPLE TYPE
D - DRIVE
C - CORE
G - GRAB

D Core recovery
Core lost
Water level drilled

GEOLOGIC BORING LOG

BORING NO.:	MPC	CONTRACTOR:	PC Exploration	DATE SPUD:	8-5-93
CLIENT:	AFCEE	RIG TYPE:	Acker Soil Max	DATE CMPL:	8-6-93
JOB NO.:	DE268.09.04	DRLG METHOD:	HSA	ELEVATION:	
LOCATION:	Site 510.8, Hill AFB UT	BORING DIA.:	8" OD	TEMP.:	90°F
GEOLOGIST:	John Ratz	DRLG FLUID	None	WEATHER:	sunny, calm
COMMENTS:					

Elev. (ft.)	Depth (ft.)	Profile	USCS	Geologic Description	Sample No.	Sample Depth(ft)	Sample Type	Penet. Res.	Remarks TIP = Bkgrnd/Reading (ppm)
	1		GW	GRAVEL, well-rounded, 1/8" to 1" dia w sm silt and clay					
				SAND, reddish brown, vf-f, well graded, moist, w tr silt, no					
			SW	odor.					
	5								
				8.5-10' SAND, SAA, lens of clayey sand at 9.2', 1½" thick.	1	18"		6-9-	HC=98 ppmv
	10			No odor present.	1610 8-5	recovery	D	10	no odor.
				10'-18.5' SAND, SAA					
	15								
				18.5'-20' SAND, reddish brown, vf-m, well graded, moist, w	2	18"		8-22-	HC=86 ppmv
	20			tr gravel 1/8" to 1/4" dia, No odor, lens of clayey sand at 19', 1" th	1635 8-5	recovery	D	28	no odor
				20'-28.5' SAND, SAA					
	25								
			SW	28.5'-30' SAND, reddish brown, vf-f, well graded, some iron	3	18"		16-31-	HC=120 ppmv
	30			staining, moist. Some gravel at 28.5' bgs, clayey sand lens 1"	0835 8-6	recovery	D	31	no odor
				thick at 29'. No odor. Tr silt.					
	35								

sl - slight
tr - trace
sm - some
& - and
@ - at
w - with

v - very
lt - light
dk - dark
bf - buff
brn - brown
blk - black

f - fine
m - medium
c - coarse
BH - Bore Hole
SAA - Same As Above
veg - Vegetation

SAMPLE TYPE
D - DRIVE
C - CORE
G - GRAB

D Core recovery
Core lost
Water level drilled

GEOLOGIC BORING LOG

BORING NO.:	MPC	CONTRACTOR:	PC Exploration	DATE SPUD:	8-5-93
CLIENT:	AFCEE	RIG TYPE:	Acker Soil Max	DATE CMPL:	8-6-93
JOB NO.:	DE268.09.04	DRLG METHOD:	HSA	ELEVATION:	
LOCATION:	Site 510.8, Hill AFB, UT	BORING DIA.:	8" OD	TEMP.:	90°F
GEOLOGIST:	John Ratz	DRLG FLUID	None.	WEATHER:	sunny, calm
COMMENTS:					

Elev. (ft.)	Depth (ft.)	Profile	USCS	Geologic Description	Sample No.	Sample Depth(ft)	Sample Type	Penet. Res.	Remarks TIP = Bkgrnd/Reading (ppm)
	35								
			SW	38.5'-40' SAND, reddish brown, vf-f, well graded, tr silt,	4	18"		12-18-	HC= 78 ppmv
	~~5~~ 40			moist, no odor in sand, hydrocarbon odor detected	0925 8-6	recovery	D	24	odor in silty sand lens
				in a silty sand lens 1½" thick at 39.2' bgs.					
	~~10~~ 45								
				48.5'-50' SAND, reddish brown, vf-f, well-graded w several 1"	5	16"		9-39-	HC= 110 ppmv
	~~15~~ 50			thick clay lenses, lenses have a strong hydrocarbon odor.	1010 8-6	recovery	D	50 for 16"	lab sample.
									TD= 51' bgs
	~~20~~ 55								
	~~25~~ 60								
	~~30~~ 65								
	~~35~~ 70								

sl - slight	v - very	f - fine	**SAMPLE TYPE**
tr - trace	lt - light	m - medium	D - DRIVE
sm - some	dk - dark	c - coarse	C - CORE
& - and	bf - buff	BH - Bore Hole	G - GRAB
@ - at	brn - brown	SAA - Same As Above	
w - with	blk - black	veg - Vegetation	

D Core recovery

Core lost

Water level drilled

LOG OF SOIL BORING

BORING NO. 510SVE-1

Geologist: Bruce Haley
Coordinates X: 0.00
Y: 0.00
Surface Elevation: 0.00
Casing Above Surface:
Reference Elevation:
Reference Description:

Aquifer:
Location: HILL AFB
Job No. 60187.02
Client: U.S. AIR FORCE
Drilling Method: 4 1/2 in. I.D. HSA

Sampling Method: SS,3 in.o.d.,2 5/8 in. I.D.,5 ft long, adv. by 4 1/2 in.I.D. HSA

Start Date: 07/14/92

Completion Date: 07/15/92

SAMP TYPE	IN. DRVN	IN. RCVD	SAMP NO.	SAMP DEPTH	BLOWS/6"	PID (headspace)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS: Flat surface Bare
SS	24	24	1	0.0		10	0		
SS	24	12	2	3.0		5			
SS	48	23	3	5.0		5	5		Dark yellowish brown (10YR42), Dry F-med sd, tr gravel - (SM)
SS	60	36	4	9.0		2			
							10		
SS	60	33	5	14.0		3			
							15		Moderate yellowish brown (10YR54), Dry F-med sd, thin layers iron stains - (SM)
SS	60	30	6	19.0		2500			
							20		

SAMPLER TYPE
SS - DRIVEN SPLIT SPOON
SH - PRESSED SHELBY TUBE
OST - OSTENBURG PISTON SAMPLER
DEN - DENISON CORE BARREL SAMPLER
SPT - STANDARD PENETRATION TEST (ASTM D 1586-84)
SHV - STAINLESS STEEL SHOVEL
NS - NO SAMPLE

GROUND-WATER DEPTH BELOW GRADE
AT COMPLETION not encountered
AFTER HRS. 0.00 FT.
AFTER 24 HRS. FT.

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.

LOG OF SOIL BORING

BORING NO. 510SVE-1

SAMP TYPE	IN. DRVN	IN. RCVD	SAMP NO.	SAMP DEPTH	BLOWS/6"	PID (headspace)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS:
							20		
SS	60	32	7	24.0		2500			
							25		
SS	60	35	8	29.0		2500			
							30		
SS	60	–	9	34.0		2500			Grayish orange (10YR74), Dry Vf-f sd, thin layers iron stains – (SM)
							35		
SS	60	35	10	39.0		23			
							40		
SS	60	28	11	44.0		2500			
							45		Moderate yellowish gray (10YR54), Dry Vf-f sd, silty sd – (SM)
SS	60	32	12	49.0		2500			Moderate yellowish brown (10YR54), Dry Fine sd, vf-silty sd – (SM)
							50		

LOG OF SOIL BORING

BORING NO. 510SVE-1

SAMP TYPE	IN. DRVN	IN. RCVD	SAMP NO.	SAMP DEPTH	BLOWS/6"	PID (headspace)	DEPTH FEET	GRAPH LOG	SURFACE CONDITIONS:
							50		
SS	60	35	13	54.0		1637			
							55		
SS	60	43	14	59.0		168			
							60		
SS	60	37	15	64.0		14			Moderate yellowish brown (10YR54), Dry Fine sd, thin layers vf silty sd – (SM)
							65		
SS	60	26	16	69.0		17			Moderate yellowish brown (10YR54), Dry Sandy clay, non plastic, tr grvl – (CL)
							70		Moderate yellowish brown (10YR54), Dry F sd, thin layers iron stains – (SM)
									Total Depth 74 ft
							75		
							80		

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.

SOIL VAPOR EXTRACTION WELL

Date 7-14-92 | Geologist Bruce Haley | Job Number 60187.02

Client Hill AFB, EMR | Well Number 510SVE-1

Driller PC Exploration
David Mott

Lic. #

Drilling Method HSA
CME 75

Bore hole diameter
8.25 OD
4.50 ID

Sealing Material
Cement/Bentonite

Type Slurry

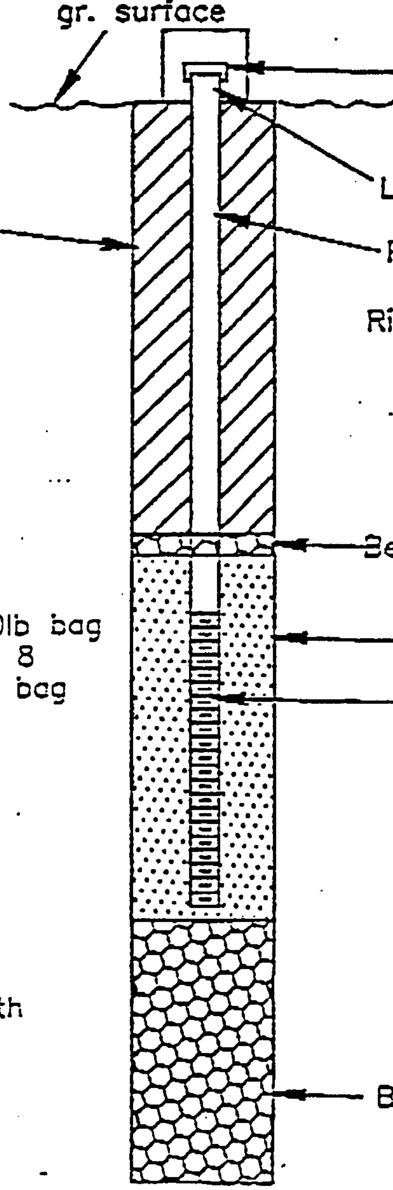
Proportions
97% 3%

Depth from 30 to 3

Pure Wyoming Bentonite 50lb bag
Gramusil Silica Sand Grade 8
100lb bag

Note:
All footages equal to depth below ground surface

gr. surface



Protective Cover yes or no
Type Steel

Length of well stick up 2.0 ft

Riser pipe diameter 2" schedule 40

Riser pipe length from 34 to 2.0 above surface

Bentonite Pellets/Slurry
from 32 to 30

Filter pack from 64 to 32

Screen diameter 2" schedule 40

Slot size 0.020

Screen set from 64 to 34

Total hole depth 74 backfill to 64

Bentonite Backfill

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

Figure 4-3

ENVIRONMENTAL SERVICES

Western Division

EA

LOG OF SOIL BORING

EA MW1

Coordinates:

Elevation top of casing:

Casing below surface:

CLIENT	LOCATION
USAF-HAFB	Tank 510.8

DRILLING AND SAMPLING METHODS: CME Rotary Rig, PC Exploration Crew, 8.25 Inch O.D. Hollow-Stem Auger, Continuous Sampling System

WATER LEVEL	86.61		
TIME	13.41		
DATE	1/18/91		
REFERENCE	TOC		

DRILLING	START	FINISH
TIME	10.30	10.00
DATE	1/9/91	1/10/91

SURFACE CONDITIONS: Snow and ice on frozen soil

DESCRIPTION by: A. T. Winters

Feet Driven	Feet Recover	OVA (Field/ Headspace)	DEPTH (Feet)	GRAPHIC LOG	DESCRIPTION
			0–2		Sandy back fill.
5	3	<2/ 500	5–9.5	SM	Silty sand, silt 20%, moderate yellowish-brown 10 YR 5/4, low plasticity, moist, no apparent structure.
3	3	60/ 300	10–13	SP	Sand, poorly-graded, fine-grained, dry, color grayish orange-pink 5 YR 7/2, no apparent structure.
2	2	50/ NA	14	SP	
5	4	30/ 500	16–20	SP	Sand, same as above except mild HC odor, minor gravel (<10%).

ENVIRONMENTAL SERVICES

Western Division — EA LOG OF SOIL BORING	EA MW1	CLIENT	LOCATION
LOG OF SOIL BORING	EA MW1	USAF-HAFB	Tank 510.8

			Depth		Description
			20		
			21		
5	1	60/ 500	22		Sand, fine-grained, strong HC odor, <10% gravel, gravel to 2 cm., dry, color pale yellowish-brown 10 YR 6/2.
			23	SP	
			24		
			25		
3	3	120/ 600	26		
			27		
			28	SP	Silty clay layers, generally 2-3 cm. thick, medium plasticity, medium hard, finely bedded with FeOx coloration on bedding planes, color light brown 5 YR 6/4.
2	1		29		
			30	SP	
3	3	<5/ 50	31		
			32		
2	2	<5/ NA	33	SP	Sand, fine-grained, color grayish-orange 10 YR 7/4, mild HC odor, dry, bedding delineated by thin (< 1 cm.) clay layers and FeOx staining.
			34		
			35		
			36		
5	5	<5/ 30	37	SP	
			38		
			39		
			40	SP	
			41		Sand, as above.
4	3	<5/ NA	42		
			43	SP	
			44		
			45		

LOG OF SOIL BORING — EA MW1

CLIENT	LOCATION
USAF-HAFB	Tank 510.8

Depth				USCS	Description
45				SP	
46				SP	Sand, as above, fine-grained, crumbles easily, moist, color moderate yellowish-brown 10 YR 5/4, bedding planes delineated by thin FeOx coloration, beds 1 cm. to 3 cm. thick.
47	5	5	<2/ 20	SP	
48				CL	
49				CL	
50				SP	
51				SP	Clay layers contain 0-20% silt and fine sand, formation soft to medium stiff, medium plasticity, color moderate brown 5 YR 4/4.
52	5	5	<2/ 10	CL	
53				SP	
54				SP	
55				SP	
56				SP	
57	5	4	<2/8	CL	
58				SP	Sand, as above, cross bedding evident.
59				SP	
60				SP/CL	
61				SP/CL	
62	5	5	<2/ NA	SP/CL	Interbedded sand and silty clay layers .5 cm. to 2 cm. thick, fine beds in both units 1-5 mm. thick. Formation descriptions as above.
63				SP/CL	
64				SP/CL	
65				SP/CL	
66				SP/CL	
67	5	5	<2/ NA	SP/CL	
68				SP/CL	
69				SP/CL	
70				SP/CL	

ENVIRONMENTAL SERVICES

Weston Division EA LOG OF SOIL BORING	EA MW1	CLIENT USAF-HAFB	LOCATION Tank 510.8

Depth				USCS	Description
70					
71					
72	5	5	<2/ <2		Interbedded sediments: sand, fine-grained, moist to dry, with 1-5 cm. thick layers of clay, medium plastic, medium stiff, as above.
73					
74					
75				SP/CL	
76					Crossbedding in sand layers, bedding marked by Fe-Ox staining.
77	5	5	<2/ <2		
78					
79					
80					
81				CL	
82	5	3	<2/ NA		
83					Sand, fine-grained, variable coloration, generally moderate yellowish-brown 10 YR 5/4 dry, crumbles easily.
84					
85					
86					First water.
87	5	3	NA	SP	
88					Sand, fine to medium-grained, as above, approx. 1% mica flakes, saturated.
89					
90					
91					
92					
93	5	3	NA		
94				SP/SM	
95					

ENVIRONMENTAL SERVICES

Western Division

LOG OF SOIL BORING

EA MW1

CLIENT	LOCATION
USAF-HAFB	Tank 510.8

			Depth	USCS	Description
5	4	NA	95–100	SP/SM	Sand, fine, saturated, as above except with 10-20% minor clay layers <1 cm. thick, (CL) as described above, and with variable silt content to 25% in some layers.
			100		T.D. 100 ft.

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APPENDIX A.3

SOIL BORING LOGS, WELL AND VAPOR PROBE

COMPLETION DETAILS

SITE 1705

(Radian Corporation, 1993)

RADIAN
CORPORATION

Monitoring Well #: T17051MW

LOG OF DRILLING OPERATIONS

PROJECT	HILL AFB SITE 1705
LOCATION	OGDEN, UTAH
TOTAL DEPTH	42.00
START DATE	11/10/92
FINISH DATE	11/10/92
GEOLOGIST	Bill Bender
APPROVED BY	
R.G.#	
DRILLING COMPANY	PC Exploration
DRILLER	Mark Clark
DRILLING METHOD	Hollow Stem Auger
EQUIPMENT	Mobile B-61
DRILL BIT TYPE AND SIZE	8.25" I.D.
BORING LOCATION (ST. ADDRESS OR DESCRIPTION)	Adjacent to Building 1705.

Depth Below Surface (ft)	Blow Count	Organic Vapor Conc. (ppmv)	Lithologic Description (Color, Texture, Moisture, USCS Class)	Construction Details
0	6/8/12/14	14.3	SILTY SAND dark brown (10 YR 3/3), fine grained, moderately sorted, subrounded, damp, (SM).	Concrete to surface. Top of cement/bentonite grout, 1' >
		4.7	SAND dark brown (10 YR 3/3), fine grained, moderately sorted, subrounded, damp, (SW).	
5		5.0	SAND orange brown (10 YR 4/6), medium grained, well sorted, subangular, damp, (SW).	4" PVC riser >
10			SANDY SILT light brown (2.5 YR 4/4), fine grained, moderately sorted, subrounded, damp, (ML).	
		14.9	SAND light brown (2.5 YR 4/4), fine grained, moderately sorted, subrounded, damp, (SW).	
15			SILTY SAND light brown (2.5 YR 4/4), very fine grained, moderately sorted, subrounded, damp, (SM).	Top of bentonite seal, 18' >
20	15/16/18/22	7.7	SANDY SILT light brown (10 YR 5/4), very fine grained, poorly sorted, subrounded, damp, (ML).	Top of 20-40 filter pack sand, 20' >
			SILT light brown (10 YR 5/4), very fine grained, well sorted, damp, (ML).	Top of 4" #304 SS 0.010" slot screen, 22' >
25	12/10/15/20	8.9	SILT brown (10 YR 4/4), very fine grained, well sorted, compact, moist, (ML).	

Ground Water Encountered ▽ 25.00

Figure 7-1

RADIAN CORPORATION

Monitoring Well #: T17051MW

LOG OF DRILLING OPERATIONS

PROJECT HILL AFB SITE 1705 LOCATION OGDEN, UTAH

Depth Below Surface (ft)	Blow Count	Sample Interval	Organic Vapor Conc. (ppmv)	Lithologic Description	Graphic Log	Construction Details
30				CLAYEY SILT light brown (10 YR 5/4), compact, moderately stiff, iron oxide banding, wet, (ML).		30
	13/11/14/18		8.6	SILTY SAND light brown (10 YR 5/4), fine grained, well sorted, subrounded, compact, wet, (SM).		
35						35
40						40
						Bottom of screen, 42' > Bottom of end plug, 42.5' >

RADIAN
CORPORATION

Air Injection Well #: T17051VW

Page 1 of 1

LOG OF DRILLING OPERATIONS

PROJECT: HILL AFB SITE 1705
LOCATION: OGDEN, UTAH
TOTAL DEPTH: 23.00
START DATE: 11/11/92
FINISH DATE: 11/12/92
GEOLOGIST: Bill Bender
APPROVED BY:
R.G.#:
DRILLING COMPANY: PC Exploration
DRILLER: Mark Clark
DRILLING METHOD: Hollow Stem Auger
EQUIPMENT: Mobile B-61
DRILL BIT TYPE AND SIZE: 8.25" I.D.
BORING LOCATION (ST. ADDRESS OR DESCRIPTION): Adjacent to Building 1705.

Depth Below Surface (ft)	Blow Count	Sample Interval	Organic Vapor Conc. (ppmv)	Lithologic Description (Color, Texture, Moisture, USCS Class)	Graphic Log	Construction Details
0				SAND dark brown (10 YR 3/3), fine grained, well sorted, subrounded, damp, (SW).		Concrete to surface. Top of cement/bentonite grout, 1' > 4" PVC riser >
5						Top of bentonite seal, 6.5' > Top of 10-20 filter pack sand, 8' >
10	35/11/18/20		113			Top of 4" PVC 0.020" slot screen, 10' >
				SILTY SAND orange brown (10 YR 5/8), fine grained, moderately sorted, subrounded, damp, (SM).		
			42.1			
15						
				SANDY SILT light brown (10 YR 5/6), very fine grained, stiff, damp, (ML).		
				SILTY SAND orange brown (10 YR 4/6), fine grained, moderately sorted, subrounded, moist, (SM).		Bottom of screen, 19.5' > Bottom of end plug, 20' > Backfilled borehole with 10-20 filter pack sand.
20	8/10/2/25		26.7			

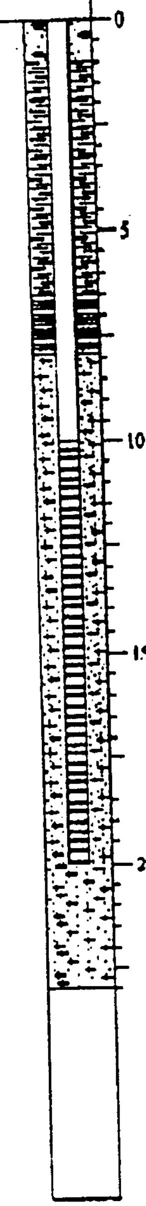


Figure 7-2

RADIAN
CORPORATION

Soil Vapor Probe #: T17052VW

Page 1 of 1

LOG OF DRILLING OPERATIONS

PROJECT: HILL AFB SITE 1705 — LOCATION: OGDEN, UTAH
TOTAL DEPTH: 25.00 — START DATE: 11/12/92 — FINISH DATE: 11/12/92
GEOLOGIST: Bill Bender — APPROVED BY: — R.G.#:
DRILLING COMPANY: PC Exploration — DRILLER: Mark Clark
DRILLING METHOD: Hollow Stem Auger — EQUIPMENT: Mobile B-61
DRILL BIT TYPE AND SIZE: 8.25" I.D.
BORING LOCATION (ST. ADDRESS OR DESCRIPTION): Adjacent to Building 1705.

Depth Below Surface (ft)	Blow Count	Sample Interval	Organic Vapor Conc. (ppmv)	Lithologic Description (Color, Texture, Moisture, USCS Class)	Graphic Log	Construction Details
0				SILTY SAND brown (7.5 YR 3/4), very fine grained, moderately sorted, subangular, damp, (SM).		Concrete to surface.
	5/5/5/7		243			Top of cement/bentonite grout, 1' >
	4/3/5/7		263			0.25" I.D. tygon tubing.
5	4/6/8/11		72			
				SAND orange brown (10 YR 4/6), fine grained, well sorted, damp, (SW).		
	6/5/8/13		95			Top of bentonite seal, 8' >
10	8/10/13/18		80			Top of 10-20 filter pack sand, 10' >
				SILTY SAND light brown (10 YR 5/3), very fine grained, moderately sorted, subangular, loose, damp, (SM).		Top of vapor probe, 11.5, >
	16/17/19/26		172	SANDY SILT light brown (10 YR 5/3), very fine grained, compact, damp, (ML).		1.5" slotted PVC probe. Bottom of soil vapor probe, 13' >
	14/15/16/19		73			
15			92	SAND brown (10 YR 6/4), fine grained, well sorted, subangular, damp, (SW).		
	13/17/18/26		91			
	14/16/18/20			SAND brown (10 YR 6/4), very fine grained, well sorted, subangular, damp, (SW).		Back filled borehole with 10-20 filter pack sand >
20	14/15/20/24		75.2	SILTY SAND light brown (10 YR 5/4), very fine grained, compact, damp, (SM).		
	13/15/13/21		103			
	15/16/18/20		35	SILTY SAND brown (10 YR 4/2), very fine grained, moist, (SM)		
25						

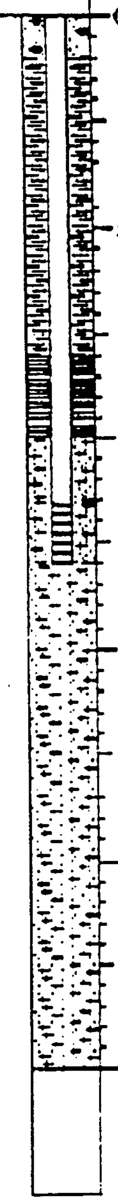


Figure 7-3

RADIAN
CORPORATION

Soil Vapor Probe #: T17053VW

LOG OF DRILLING OPERATIONS

PROJECT: HILL AFB SITE 1705 LOCATION: OGDEN, UTAH
TOTAL DEPTH: 25.00 START DATE: 11/12/92 FINISH DATE: 11/12/92
GEOLOGIST: Bill Bender APPROVED BY: R.G.#:
DRILLING COMPANY: PC Exploration DRILLER: Mark Clark
DRILLING METHOD: Hollow Stem Auger EQUIPMENT: Mobile B-61
DRILL BIT TYPE AND SIZE: 8.25" I.D.
BORING LOCATION (ST. ADDRESS OR DESCRIPTION): Adjacent to Building 1705.

Depth Below Surface (ft)	Blow Count	Organic Vapor Conc. (ppmv)	Lithologic Description (Color, Texture, Moisture, USCS Class)	Construction Details
0		3.2	SILTY SAND dark brown (10 YR 2/1), fine grained, moderately sorted, damp, (SM).	Concrete to surface. Top of cement/bentonite grout, 1' >
5				
			SAND brown orange (10 YR 5/6), fine grained, well sorted, damp, (SW).	
		5.0		0.25" I.D. tygon tubing
10	14/11/25/25	32	SILTY SAND orange brown (10 YR 6/6), fine grained, moderately sorted, damp. (SM).	Top of bentonite seal, 10' >
	22/25/25/30	78		
			SAND light brown (10 YR 6/4), fine grained, well sorted, subangular, damp, (SW).	Top of 10-20 filter pack sand, 12' >
	13/23/23/25	122		Top of vapor probe, 13.9' > 1.5' slotted PVC probe >
15	18/20/22/23	119	SANDY SILT orange brown (10 YR 5/6), very fine grained, damp, (ML).	Bottom of soil vapor probe, 15.4' >
			SILTY SAND light brown (10 YR 6/4), fine grained, moderately sorted, subrounded, damp, (SM).	
	10/18/20/30	43		
	11/13/21/28	73		
20				
	7/11/14/19		SANDY SILT dark brown (10 YR 4/3), very fine grained, wet. (ML)	Back filled borehole with 10-20 filter pack sand >
	10/13/15/18			
25				

Figure 7-4

APPENDIX A.4

SOIL BORING LOGS, WELL AND VAPOR PROBE

COMPLETION DETAILS

SITE 40002

(Engineering-Science, Inc., 1993)

ENGINEERING-SCIENCE, INC - BORING LOG

WELL NUMBER: SB-6 LOCATION: UTTR WEATHER: Cloudy Cold

DATE: 11/16/92 LOGGED BY: JFB SAMPLING METHOD: 2-in ID Split-Spoon

DRILLING METHOD: HSA DRILLED BY: PC Exploration SEAL: HOLE DIAMETER: 10 1/4 TOTAL DEPTH: 37 ft.

MC	S	DEN	T	ST	OV	DEP	SR	SPT	LITHOLOGY/REMARKS
									Fill material
						1			
						2			
						3			
						4			
						5			Fill
					0.0	6	60		
						7			
						8			
						9			
						10			Fill
					0.0	11	45		
						12			
						13			Fill Uniform 1/8 gravel
						14			Original clay
						15			Discolored white with black substance Strong odor Moist Cohesive (very)
					3.3	16	28		
						17			
					1200	18	35		
					71	19			Light sand
						20	32		

ENGINEERING-SCIENCE, INC - BORING LOG

WELL NUMBER: SB-8 LOCATION: UTTR WEATHER: Sunny Mild

DATE: 11/18/92 LOGGED BY: JFB SAMPLING METHOD: 2-in ID Split-Spoon

DRILLING METHOD: HSA DRILLED BY: PC Exploration SEAL: HOLE DIAMETER: 10 1/4 TOTAL DEPTH: 47.5 ft.

IC	S	DEN	T	ST	OV	DEP	SR	SPT	LITHOLOGY/REMARKS
						1			
						2			
						3			
						4			
						5			Fine silt and sand, some clay 10 yr 7/3 pale brown Semi cohesive 100% recovery
					20	6	24		
						7			
						8			
						9			
						10			
						11			
						12			
						13			
						14			Very fine sand, some silt Dry 2.5 yr 8/2 white Non-cohesive
					1866	15	22		
						16			
						17			
						18			
						19			
						20			

ENGINEERING-SCIENCE, INC - BORING LOG

WELL NUMBER: SB-8 | LOCATION: UTTR | WEATHER: Sunny Mild

DATE: 11/18/92 | LOGGED BY: JFB | SAMPLING METHOD: 2-in ID Split-Spoon

DRILLING METHOD: HSA | DRILLED BY: PC Exploration | SEAL: | HOLE DIAMETER: 10 1/4 | TOTAL DEPTH: 47.5 ft.

MC	S	DEN	T	ST	OV	DEP	SR	SPT	LITHOLOGY/REMARKS
									Fine brown sand, some silt and clay Dry 2.5 yr 5/4 light olive brown Cohesive
						21			
					1846		21		
						22			
						23			
						24			
						25			
						26			
						27			
						28			
						29			
						30			Fine brown sand, some silt and clay Same as above
					1250	31	23		
						32			
						33			
						34			
						35			Fine brown sand, some silt and clay Same as above
					0.0	36			
						37			
						38			
						39			
						40			

ENGINEERING-SCIENCE, INC - BORING LOG

WELL NUMBER: SB-8	LOCATION: UTTR	WEATHER: Sunny Mild	
DATE: 11/18/92	LOGGED BY: JFB	SAMPLING METHOD: 2-in ID Split-Spoon	
DRILLING METHOD: HSA	DRILLED BY: PC Exploration	SEAL:	HOLE DIAMETER: 10 1/4 TOTAL DEPTH: 47.5 ft.

MC	S	DEN	T	ST	OV	DEP	SR	SPT	LITHOLOGY/REMARKS
									Fine brown sand, some silt and clay Same as above
						41			
						42			
						43			
						44			
						45			
						46			Fine brown sand, some silt and clay Same as above
						47			
						48			

ENGINEERING-SCIENCE, INC - BORING LOG

WELL NUMBER: SB-9 LOCATION: UTTR WEATHER: Sunny Mild

DATE: 11/18/92 LOGGED BY: JFB SAMPLING METHOD: 2-in ID Split-Spoon

DRILLING METHOD: HSA DRILLED BY: PC Exploration SEAL: HOLE DIAMETER: 10 1/4 TOTAL DEPTH: 42 ft.

MC	S	DEN	T	ST	OV	DEP	SR	SPT	LITHOLOGY/REMARKS
						1			
						2			
						3			
						4			Fill
						5			Auger cuttings Silt and sand, some clay Semi-cohesive 2.54 8/2 white
						6			
						7			
						8			
						9			
						10			
						11			
						12			
						13			
						14			Silt and sand, some clay Dry 10 yr 7/6 yellow to 10 yr 8/1 white 100% recovery
					3196	15	28		
						16			
						17			
						18			
						19			
					1001	20			

ENGINEERING-SCIENCE, INC - BORING LOG

WELL NUMBER: SB-9 LOCATION: UTTR WEATHER: Sunny Mild

DATE: 11/18/92 LOGGED BY: JFB SAMPLING METHOD: 2-in ID Split-Spoon

DRILLING METHOD: HSA DRILLED BY: PC Exploration SEAL: HOLE DIAMETER: 10 1/4 TOTAL DEPTH: 42 ft.

MC	S	DEN	T	ST	OV	DEP	SR	SPT	LITHOLOGY/REMARKS
					1001	21	32		Very fine sand, some silt Dry 25 yr 7/4 pale yellow Non-cohesive 100% recovery
						22			
						23			
						24			
						25			
						26			
						27			
						28			
						29			
						30			
					66	31			Very fine sand, silt, some clay Dry 2.5 yr 5/4 light olive brown Semi-cohesive 100% recovery
						32			
						33			
						34			
						35			
						36			Very fine sand and silt Dry 10 yr 8/1 white Non-cohesive
						37			
						38			
						39			
						40			

ENGINEERING-SCIENCE, INC - BORING LOG

WELL NUMBER: SB-9 LOCATION: UTTR WEATHER: Sunny Mild

DATE: 11/18/92 LOGGED BY: JFB SAMPLING METHOD: 2-in ID Split-Spoon

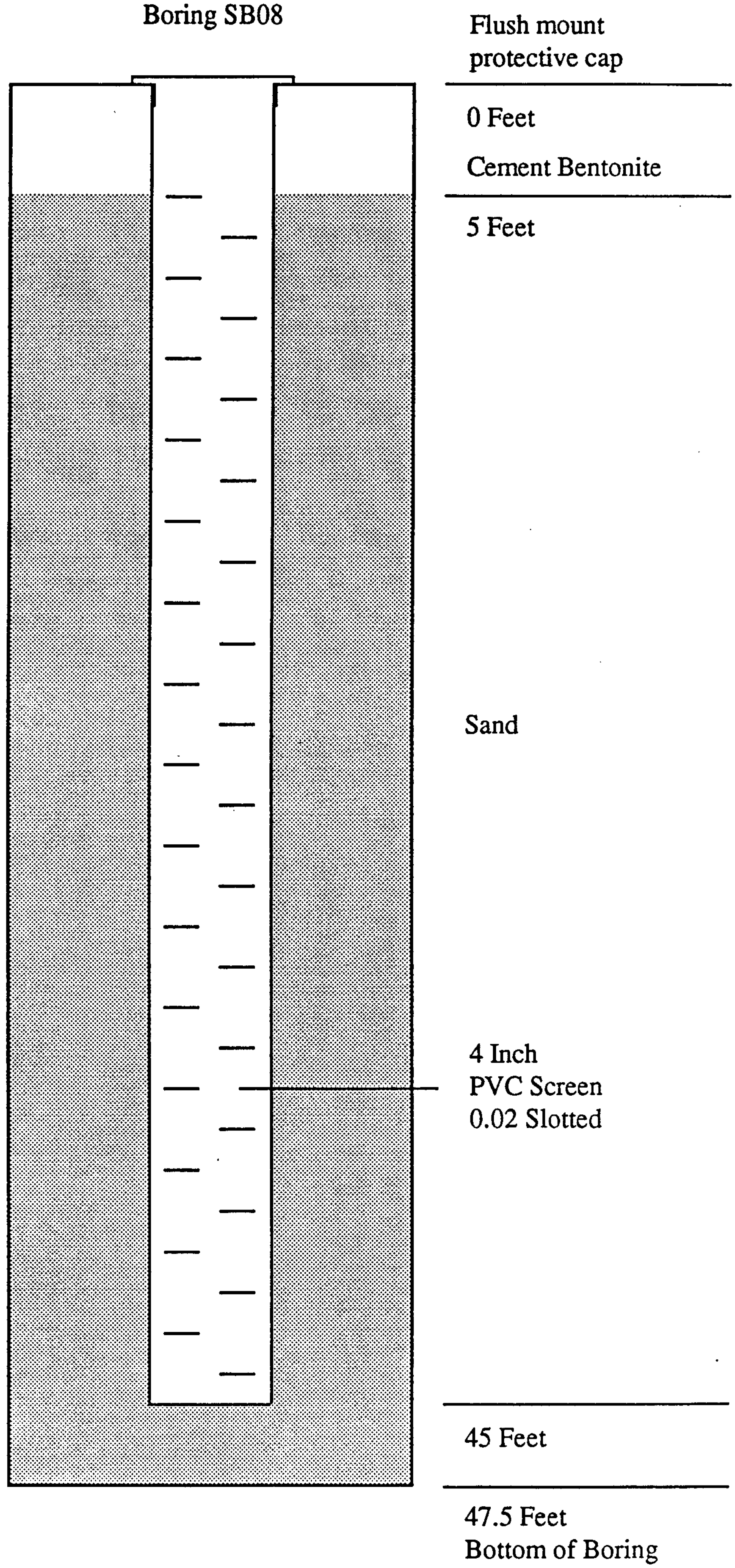
DRILLING METHOD: HSA DRILLED BY: PC Exploration SEAL: HOLE DIAMETER: 10 1/4 TOTAL DEPTH: 42 ft.

MC	S	DEN	T	ST	OV	DEP	SR	SPT	LITHOLOGY/REMARKS
									Very fine sand and silt Dry 10 yr 8/1 white Non-cohesive
						41			
					0.0				
						42			Bottom of boring

UTTR Refueling Station

Air Injection Well

Boring SB08

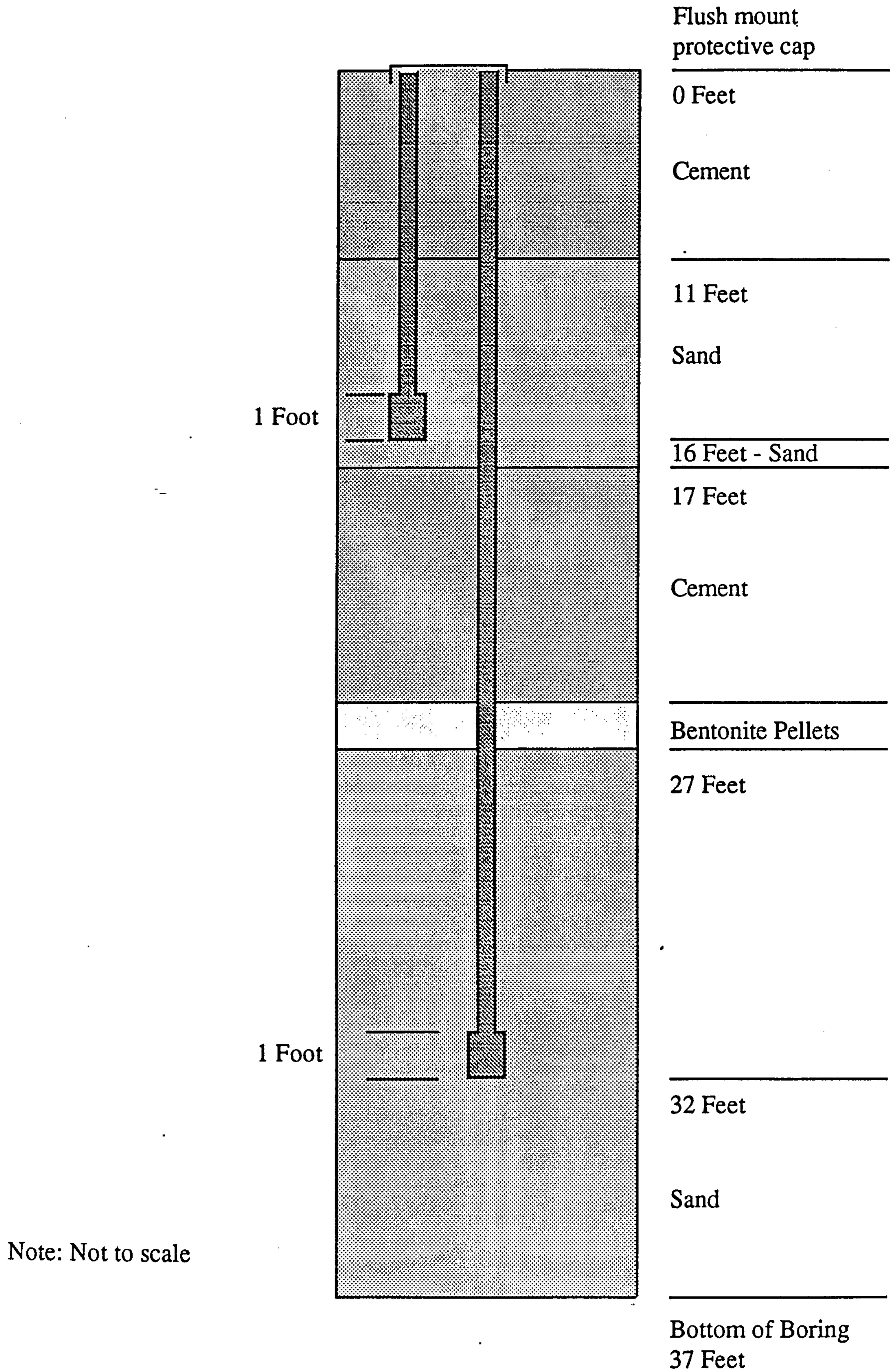


Note: Not to scale

UTTR Refueling Station

Soil Vapor Monitors

Boring SB06 and SB09



APPENDIX B

BLOWER OPERATION AND MAINTENANCE MANUAL

GENERIC BLOWER SYSTEM OPERATIONS AND MAINTENANCE MANUAL FOR EXTENDED PILOT TESTING SYSTEM

Prepared for:

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE

BROOKS AFB, TEXAS

USAF CONTRACT F33615-90-D-4010, DELIVERY ORDER 14

April 1993

Prepared by:

Engineering-Science, Inc.
1700 Broadway, Suite 900
Denver, Colorado

A7-15-43

CONTENTS

FIGURES

SECTION 1

INTRODUCTION

This document has been prepared by Engineering-Science, Inc. to support the bioventing initiative contract awarded by the Air Force Center for Environmental Excellence. The contract involves the conducting of bioventing pilot tests at 35 sites on 23 Air Force bases across the United States.

At most sites, bioventing systems will be installed upon completion of the initial bioventing pilot tests for the purpose of extended pilot testing. These systems will operate for a 1-year period to provide further information as to the feasibility of the technology at each site, and to provide interim remedial action.

This Operations and Maintenance Manual has been created for sites at which regenerative or rotary-vane blowers have been installed for extended pilot testing. Basic maintenance of these systems is the responsibility of the Air Force facility. This manual is to be used by facility personnel to guide and assist them in operating and maintaining the blower system. Section 2 provides a summary of the bioventing system components installed. Section 3 of this document describes the blower system. Section 4 details the maintenance requirements and provides maintenance schedules. Section 5 describes the system monitoring that is required to forecast system maintenance needs and to provide data for the extended pilot test. Blower performance curves and relevant service information for regenerative and rotary-vane blowers are provided in Appendices A and B, respectively, and data collection sheets are provided in Appendix C.

SECTION 2

BLOWER SYSTEM CONFIGURATION SUMMARY

System Type (injection, extraction) ______________

Blower (regenerative, rotary vane) ______________

Blower Model ______________

Motor (Hp) ______________

Knock-Out Chamber (yes, no) ______________

Sampling Port (yes, no) ______________

Inlet Temperature Gauge (range) ______________

Inlet Pressure/Vacuum Gauge (range) ______________

Inlet Filter (part no.) ______________

Outlet Temperature Gauge (range) ______________

Outlet Pressure/Vacuum Gauge (range) ______________

Pressure/Vacuum Relief Valve Set @ (give unit of measure) ______________

SECTION 3

BIOVENTING SYSTEM OPERATION

3.1 PRINCIPLE OF OPERATION

Bioventing is the forced injection of fresh air, or withdrawal of soil gas, to enhance the supply of oxygen for *in situ* bioremediation. Either a pressure (air injection) or vacuum (vapor extraction) blower unit is used to inject or withdraw air into or from the soil, thereby supplying fresh air with 20.8 percent oxygen to the contaminated soils. Once oxygen is provided to the subsurface, existing bacteria will proceed with the breakdown of fuel residuals.

At ____ a ____________________ blower system has been installed.

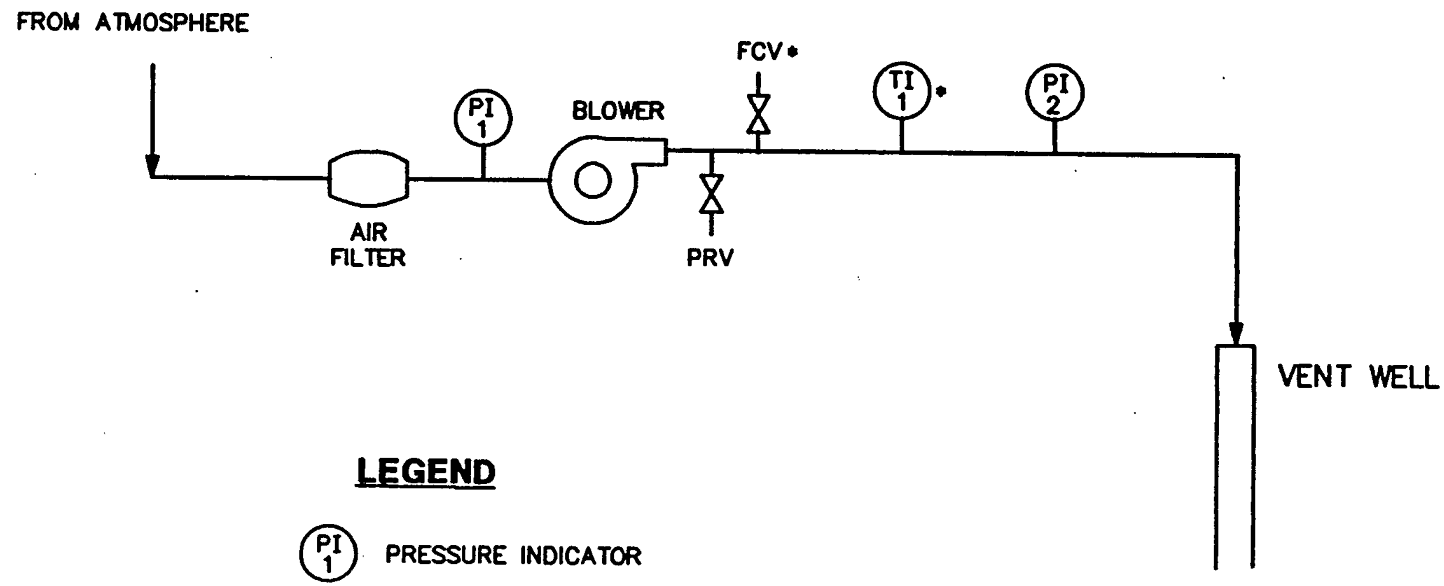
3.2 SYSTEM DESCRIPTION

3.2.1 Blower System

A ____________ blower powered by a ______ horsepower direct-drive motor is the workhorse of the bioventing system. This blower is rated at a flow rate of ___ standard cubic feet per minute (scfm) at a pressure of ___________ ; however, the actual performance of the blower will vary with changing site conditions. As installed, the blower was producing an estimated flow rate of ___ scfm at a pressure of _______. Vapor extraction systems may include an inlet knockout chamber for water condensation. All systems include an air filter to remove any particulates which are entrained in the air stream, and several valves and monitoring gauges which are described in the next section. A schematic of the blower system installed at ______________________________ is shown on Figure 3.1. Corresponding blower performance curves, and relevant service information are provided in Appendices A and B.

3.2.2 Monitoring Gauges

The bioventing system is equipped with vacuum and pressure gauges, temperature gauges, and a sampling port (vapor extraction only). Generally, gauges have been installed on the air injection system at the following locations: a vacuum gauge in the inlet piping and a pressure gauge in the outlet piping. For vapor extraction systems gauges are generally installed as follows: vacuum gauges in the



LEGEND

PI 1 PRESSURE INDICATOR
TI 1 TEMPERATURE INDICATOR
FCV FLOW CONTROL VALVE
PRV PRESSURE RELIEF VALVE
* OPTIONAL

FIGURE 3.1

TYPICAL BLOWER SYSTEM INSTRUMENTATION DIAGRAM FOR AIR INJECTION

ENGINEERING–SCIENCE, INC.
Denver, Colorado

93DN0413, 04/05/93 at 12:54

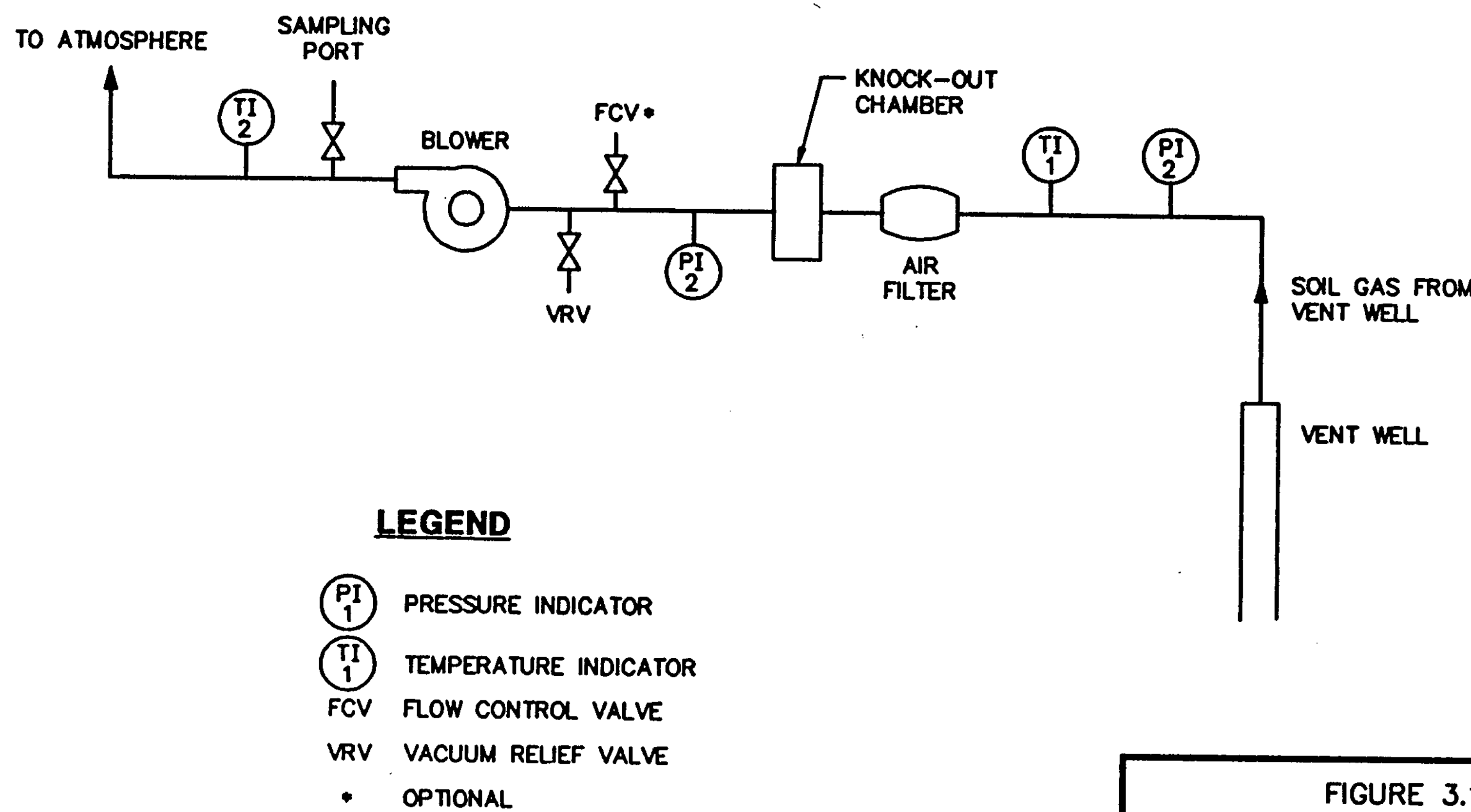


FIGURE 3.1

TYPICAL BLOWER SYSTEM INSTRUMENTATION DIAGRAM FOR AIR EXTRACTION

ENGINEERING-SCIENCE, INC.
Denver, Colorado

93DN0414, 04/02/93 at 11:10

inlet piping and at the knock-out chamber (as applicable), and a pressure gauge in the discharge piping. See Figure 3.1 for the locations of the gauges installed on the blower system at this site.

Temperature gauges may be located at the inlet and outlet of the blower system. These gauges are used to monitor the inlet and outlet temperature to determine the change in temperature across the blower. For air injection systems, ambient air temperature should be used when an inlet temperature gauge is not present. For vapor extraction systems, the inlet temperature is also used as an estimate of soil gas temperatures in the contaminated soil zone. See Figure 3.1 for the location(s) of the temperature gauges installed on the blower system at this site.

A sample port is located in the discharge piping on the outlet side of vapor extraction systems only. This sample port is used to collect offgas that is analyzed for carbon dioxide/oxygen and volatile organic compound concentrations. See Figure 3.1 for the location of the sampling port installed on the blower system at this site.

SECTION 4

SYSTEM MAINTENANCE

Although the motor and blower are relatively maintenance free, periodic system maintenance is required for proper operation and long life. Recommended maintenance procedures and schedules are described in detail in the instruction manuals included in Appendices A and B and briefly summarized in this section.

Filter inspection and knock-out chamber draining (as applicable) must be performed with the system turned off. To re-start the motor, open the manual air dilution valve (red handle) to protect the motor from excessive strain, start motor, and slowly close dilution valve. If the handle has been removed from the manual air dilution valve, do not open the valve or otherwise change the setting (it has been pre-set for a specific flow rate) before re-starting the blower.

4.1 Blower/Motor

The blower and motor are relatively maintenance free and should not require any periodic maintenance during the 1-year extended testing period. Both blower and motor have sealed bearings and do not require lubrication.

4.2 KNOCK-OUT CHAMBER

This section applies only to vapor extraction systems equipped with moisture knock-out chamber. To avoid damage caused by passing liquids solids through the blower a knock-out chamber has been installed in-line before the blower.

Free liquid should not be pumped through the blower. The knock-out chamber installed in-line before the blower intercepts entrained liquid, preventing damage to the blower. The knock-out chamber should be drained into an appropriate container once a month for the first few months and at less frequent intervals thereafter, if it appears that this will be sufficient to keep liquid from building up in the knock-out chamber. Condensation generally increases during the cold winter months. A facility employee should determine the best schedule for draining the knock-out chamber. The knock-out chamber can be drained by turning the system off and removing the cap or opening the valve at the base of the knock-out chamber. When all of the liquid has drained out, the system can be turned back on. It is recommended when re-starting the system that the air dilution valve (red-handled valve) be opened to protect the motor from excessive strain. If oily, drained liquids should be disposed of in an oil/water separator.

4.3 AIR FILTER

To avoid damage caused by passing solids through the blower, an air filter has been installed in-line before the blower. The filter element is paper and is accompanied by a polyurethane foam prefilter. The filter should be checked weekly for the first 2 months of operation. Again, a facility employee should determine the best schedule for filter replacement. The polyurethane prefilters can be washed with lukewarm water and a mild detergent. Paper filter elements should never be washed, but should be disposed of and replaced as necessary. When the pressure or vacuum drop across the filter is above 15 inches of water, a dirty filter element should be suspected, and cleaning or replacement should be performed.

To remove the filter, loosen the three clamps or the wing nut, lift the metal top off the air filter, and lift the air filter from the metal housing. Remove the polyurethane prefilter (if applicable) and wash before replacing. When replacing the filter, be careful that the rubber seals remain in place.

The filter element is manufactured by Solberg Manufacturing, Inc. in Itasca, Illinois. Their telephone number is (708) 773-1363. Additional filters can also be obtained through Engineering-Science, Inc. in Denver, Colorado. The ES contacts are Mr. Brian Blicker and ________________ and they can be reached at (303) 831-8100. The filter model number is ____________________, and the number for the replacement element is ________________. It is recommended that ____________________ keep at least one spare air filter at the site, four spare filters were supplied with the blower system.

4.4 MAINTENANCE SCHEDULE

The following maintenance schedule is recommended for this system. During the initial months of operation more frequent monitoring is recommended to ensure that any startup problems are quickly corrected. A daily drive-by inspection is recommended during the initial 2 weeks of operation to ensure that the blower system is still operating with no unusual sounds. Data collection sheets that can be used to record maintenance activities are included in Appendix C.

Maintenance Item	Maintenance Frequency
Filter	Check once per month, wash or replace as necessary (see Section 4.3).
Knock-out chamber	Drain once per month initially, then periodically (see Section 4.2).

4.5 MAJOR REPAIRS

Blowers systems are very reliable when properly maintained. Occasionally, a motor or blower will develop a serious problem. If a blower system fails to start, and a qualified electrician verifies that power is available at the blower or starter,

the Engineering-Science, Inc. site manager ____________________ should be called at (___)__________. ES is responsible for major repairs during the first year of operation.

SECTION 5

SYSTEM MONITORING

5.1 BLOWER PERFORMANCE MONITORING

To monitor the blower performance, vacuum, pressure, and temperature will be measured. These data should be recorded weekly on a data collection sheet (provided in Appendix C). All measurements should be taken at the same time while the system is running. Because the system is loud, hearing protection should be worn at all times.

5.1.1 Vacuum/Pressure

With hearing protection in place, open the blower enclosure and record all vacuum and pressure readings directly from the gauges (in inches of water or psi). Record the measurements on a data collection sheet (Appendix C).

5.1.2 Flow Rate

The flow rate through the vent well and soils can be calculated when the inlet vacuum and outlet pressure of the blower are known. This pressure change across the blower (vacuum + pressure) can be compared to the performance curves for the blower in Appendix A or Appendix B to determine the approximate flow rate.

5.1.3 Temperature

With hearing protection in place, open the blower enclosure and record the temperature readings directly from the gauges in degrees Fahrenheit (°F). Record the measurements on a data collection sheet (provided in Appendix C). The temperature change can be converted to degrees Celsius (°C) using the formula °C = (°F - 32) X 5/9.

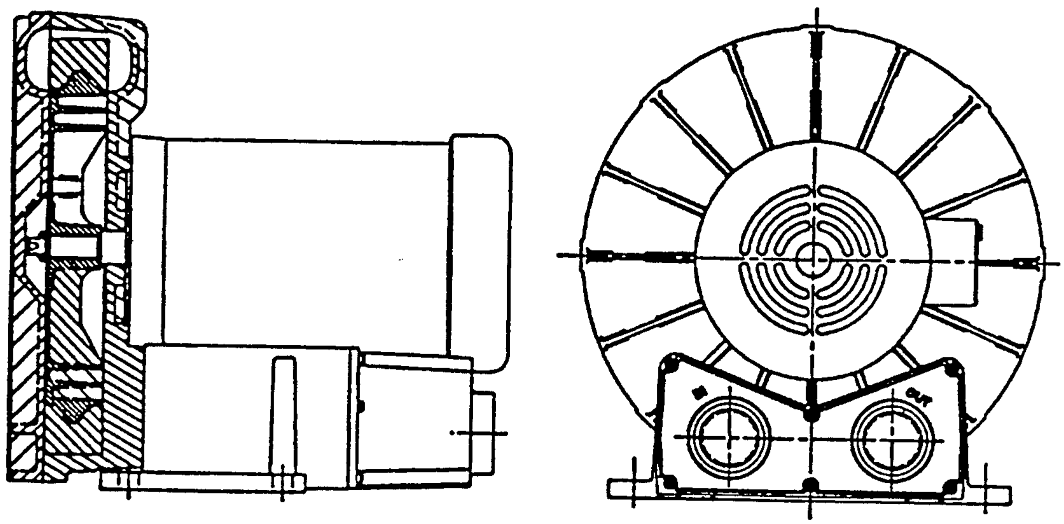
5.3 MONITORING SCHEDULE

The following monitoring schedule is recommended for this system. During the initial months of operation, more frequent monitoring is recommended to ensure that any start up problems are quickly corrected. Data collection sheets have been provided to assist your data collection and are included in Appendix C.

Monitoring Item	Monitoring Frequency
Vacuum/Pressure	Daily during first week, then once per week.
Temperature	Daily during first week, then once per week.

Post Office Box 97
Benton Harbor, Michigan 49023-0097
Ph: 616/926-6171
Fax: 616/925-8288

Maintenance Instructions for Gast Standard Regenerative Blowers



For original equipment manufacturers special models, consult your local distributor

Gast Rebuilding Centers

Gast Mfg. Corp.
2550 Meadowbrook Rd.
Benton Harbor MI. 49022
Ph: 616/926-6171
Fax: 616/925-8288

Gast Mfg Corp.
505 Washington Avenue
Carlstadt, N. J. 07072
Ph: 201/933-8484
Fax: 201/933-5545

Brenner Fiedler. & Assoc.
13824 Bentley Place
Cerritos, CA. 90701
Ph: 213/404-2721
Fax: 213/404-7975

Wainbee, Limited
121 City View Drive
Toronto, Ont. Canada M9W 5A9
Ph: 416/243-1900
Fax: 416/243-2336

Wainbee, Limited
215 Brunswick Drive
Pointe Claire, P.Q. Canada H9R 4R7
Ph: 514/697-8810
Fax: 514/697-3070

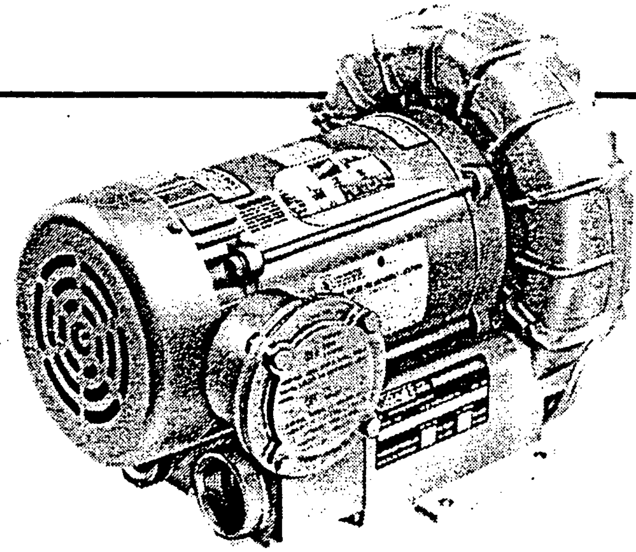
Gast Mfg. Co. Limited.
Halifax Rd, Cressex Estate
High Wycombe, Bucks HP12 3SN
Ph. 44 494 523571
Fax: 44 494 436588

Japan Machinery Co. Ltd.
Central PO Box 1451
Tokyo 100-91 Japan
Ph: 813/3573-5421
Fax: 813/3571-7865

For Soil Remediation to 260 cfm

GAST

R4, R5, R6P Series



MODEL R4 SERIES
48" H_2O MAX. VAC., 88 CFM OPEN FLOW

MODEL R5 SERIES
60" H_2O MAX. VAC., 145 CFM OPEN FLOW

MODEL R6P SERIES
90" H_2O MAX. VAC., 260 CFM OPEN FLOW

PRODUCT FEATURES

- Explosion-proof motors UL (class 1, group D; class 2, groups F & G)
- Sealed air stream
- Rugged construction
- Low maintenance

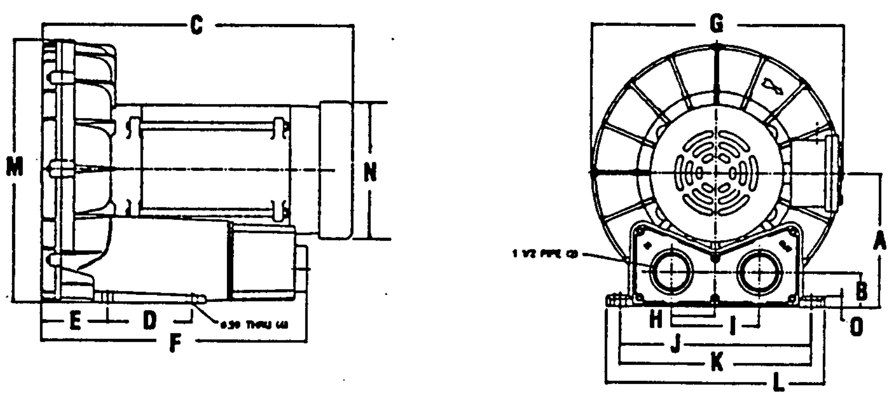
RECOMMENDED ACCESSORIES

- Inlet filter AJ151G (Reducing filter plumbing from 2½" to 1½" is needed to accommodate filter on R4 and R5 models.)
- Relief valve AG258
- Vacuum gauge AE134

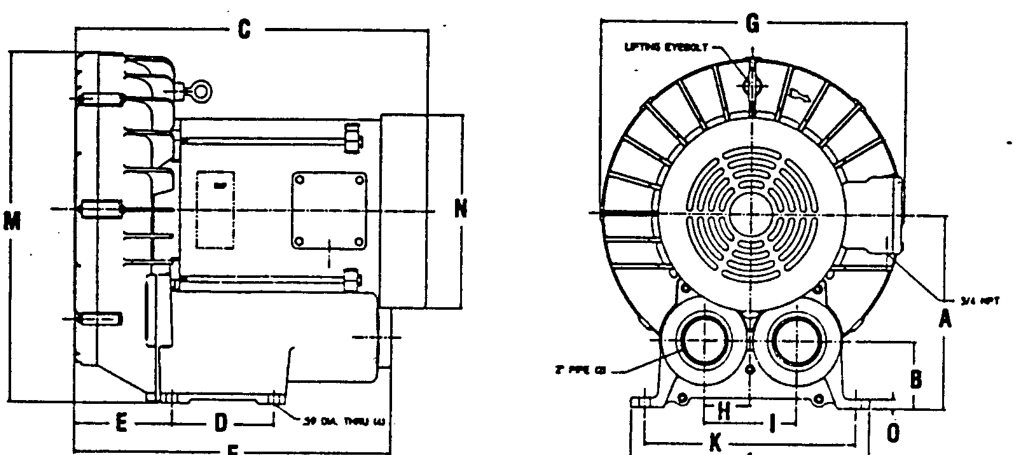
Product Dimensions Metric (mm) U.S. Imperial (Inches)

Model	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
R4110N-50	157	43	360	95	72	316	313	50	101	225	227	254	293	175	11
	6.18	1.68	14.16	3.75	2.85	12.44	12.31	1.98	3.96	8.86	8.93	10.00	11.73	6.88	.44
R4310P-50	157	43	360	95	72	316	313	50	101	225	227	254	293	175	11
	6.18	1.68	14.17	3.75	2.84	12.44	12.31	1.98	3.96	8.86	8.93	10.00	11.73	6.88	.44
R5325R-50	178	46	423	114	91	361	344	60	121	260	262	298	350	183	15
	7.00	1.82	16.66	4.50	3.58	14.22	13.56	2.38	4.75	10.25	10.31	11.75	13.78	7.19	.59
R6P355R-50	248	80	482	140	137	438	428	64	127	-	290	325	463	257	13
	9.77	3.15	18.98	5.51	5.39	17.25	16.87	2.50	5.00	-	11.42	12.80	18.21	10.12	.50

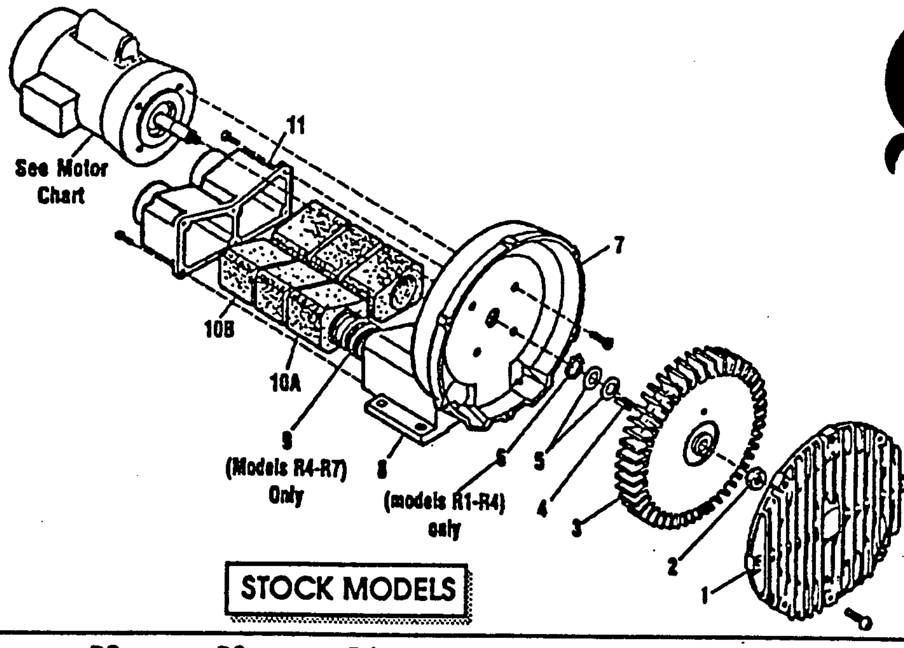
Model R4 Series
Model R5 Series



Model R6P Series



NOTE: These units with explosion-proof motors are designed specifically for qualified OEMs in the soil remediation industry. They are not intended to be applied for other uses without written acknowledgement from an authorized employee of Gast Manufacturing Corporation.



STOCK MODELS

Part Name	R1	R2	R3	R4	R5	R6	R6P	R6PP/R6PS	R7
#1 Cover	AJ101A	AJ101B	AJ101C	AJ101D	AJ101EQ	AJ101F	AJ101K	(2)AJ101KA	AJ101G
#2 Stopnut	BC187	BC187	BC181	BC181	BC181	BC181	BC181	(2)BC182	BC183
#3 Impeller	AJ102A	AJ102BQ	AJ102C	AJ102D	AJ102E	AJ102FR	AJ102K	(2)AJ102KA	AJ102GA
#4 Square Key	AH212C	AH212	AB136A	AB136D	AB136	AB136	AB136	(2)AB136	AC628
#5 Shim Spacer (s)	AJ132	AE686-3	AJ109	AJ109	AJ109	AJ116A	AJ116A	AJ116A	AJ110
#6 Retaining Ring	AJ145	AJ145	AJ149	AJ149					
#7 Housing	AJ103A	AJ103BQ	AJ103C	AJ103DR	AJ103E	AJ103F	AJ103K	AJ103KD	AJ103GA
#8 Muffler Box					AJ104E	AJ104F			
#9 Spring				AJ113DR	AJ113DQ	AJ113FQ	AJ113FQ		AJ113G
#10A Foam	(4)AJ112A	(4)AJ112B	(4)AJ112C	(4)AJ112DS	(4)AJ112ER	(6)AJ112F	(8)AJ112K		(8)AJ112GA
#10B Foam		(2)AJ112BQ	(2)AJ112CQ	(2)AJ112DR	(2)AJ112EQ				
#11 Muffler Extension/ Adapter Plate	AJ106H	AJ106BQ	AJ106CQ	AJ106DQ	AJ106EQ	AJ106FQ	AJ104K		AJ104GA
Shim Kit	K396	K396							K395

MOTOR CHART

REGENAIR MODEL NUMBER	MOTOR NUMBER	MOTOR SPECIFICATIONS 60 HZ VOLTS	50 HZ VOLTS	PHASE
R1102	J111X	115/208-230	110/220-240	1
R1102C	J112X	115		1
R2103	J311X	115/208-230	110/220	1
R2105	J411X	115/208-230	110/220	1
R2303A	J310	208-230/460	220/380-415	3
R2303F	J313	208-230	220	3
R3105-1/R3105-12	J411X	115/208-230	110/220-240	1
R3305A-1/R3305A-13	J410	208-230/460	220/380-415	3
R4110-2	J611AX	115/208-230	110/220-240	1
R4310A-2	J610	208-230/460	220/380-415	3
R5125-2	J811X	115/208-230		1
R5325A-2	J810X	208-230/460	220/380-415	3
R6125-2	J811X	115/208-230		1
R6325A-2	J810X	208-230/460	220/380-415	3
R6335A-2	J910X	208-230/460	220/380-415	3
R6150J-2	J1013	230		1
R6350A-2	J1010	208-230/460	220/380-415	3
R6P335A	J910X	208-230/460	220/380-415	3
R6P350A	J1010	208-230/460	220/380-415	3
R6P355A	J1110A	208-230/460	220/380-415	3
R7100A-2*	J1210B	208-230/460	220/380-415	3
R6PP/R6PS3110M	JD1100	208-230/460	220/380-415	3

* No lubrication needed at start up. Bearings lubricated at factory.

* Motor is equipped with alemite fitting. Clean tip of fitting and apply grease gun. Use 1 to 2 strokes of high quality ball bearing grease.

Consistency	*Type*	*Typical Grease*
Medium	Lithium	Shell Dolium R

Hours of service per year	*Suggested Relube Interval*
5,000	3 years
Continual Normal Application	1 year
Seasonal service motor idle for 6 months or more	1 year beginning of season
Continuous-high ambients, dirty or moist applications.	6 months

60 Hz FLOW DATA (CFM)

All performance figures relate to stock models. A few high pressure units may be available. Consult your local distributor.

Regenair Model Number	PRESSURE 0"H_2O	20"H_2O	40"H_2O	60"H_2O	80"H_2O	100"H_2O	Maximum Pressure "H_2O"*
R1	26	14					28
R2	42	26					38
R3105-1	52	38	14				42
R3105-12	52	36	23				55
R3305A-13	52	36	23				55
R4	90	70	50				52
R5	145	130	100				65
R6125-2	200	180					35
R6325A-2	200	180	152				40
R6335A-2	205	175	155	135			70
R6350A-2	200	180	150	130	110	80	105
R6P335A	290	250					30
R6P350A	300	260	230	200			60
R6P355A	300	260	230	200	160		90
R7100A-2	420	380	340	310	280	230	115
R6PP311OM	485	452	420	380	330		95
R6PS311OM	265	258	252	244	236	226	170

Regenair Model Number	VACUUM 0"H_2O	20"H_2O	40"H_2O	60"H_2O	80"H_2O	Maximum Vacuum "H_2O"*
R1	25	14				26
R2	40	22				34
R3105-1	50	34	9			40
R3105-12	51	34	20			50
R3305A-13	51	34	20			50
R4	82	62	39			48
R5	140	115	90	50		60
R6125-2	190	155	125			45
R6325A-2	190	155	125			45
R6335A-2	190	150	125	100		75
R6350A-2	190	180	150	100	70	90
R6P335A	270	230				37
R6P350A	280	240	210	170		70
R6P355A	280	240	210	170	100	86
R7100A-2	410	350	300	250	170	90
R6PP311OM	470	425	375	320	220	80
R6PS311OM	240	225	210	195	175	130

***This number indicates the maximum static pressure differential recommended (with cooling air still flowing through unit). In general, units 1hp or less can be dead headed. Check with local representative or distributor to verify which models apply.**

Operation of the blower above the recommended maximum duty will cause premature failure due to the build up of heat damaging the components.

Performance data was determined under the following conditions:

1) Unit in a temperature stable condition.
2) Test conditions: Inlet air density at 0.075lbs. per cubic foot. (20°C(68°F), 29.92 in. Hg(14.7PSIA)).
3) Normal performance variations on the resistance curve within +/- 10% of supplied data can be expected.
4) Specifications subject to change without notice.
5) All performance at 60Hz operation.

70-6100
F2-205/8/92
AK811 Rev. E

GAST

Post Office Box 97
Benton Harbor, MI. 49023-0097
Ph: 616/926-6171
Fax: 616/925-8288

INSTALLATION AND OPERATING INSTRUCTIONS FOR GAST HAZARDOUS DUTY REGENAIR BLOWERS

This instruction applies to the following models ONLY: R3105N-50, R4110N-50, R4310P-50, R4P115N-50, R5125Q-50, R5325R-50, R6130Q-50, R6P155Q-50, R6350R-50, R6P355R-50 and R7100R-50.

Gast Authorized Service Facilities are Located in the locations listed below

Gast Manufacturing Corporation
505 Washington Avenue
Carlstadt, N. J. 07072
Ph: 201/933-8484
Fax: 201/933-5545

Gast Manufacturing Corporation
2550 Meadowbrook Road
Benton Harbor, MI. 49022
Ph: 616/926-6171
Fax: 616/925-8288

Brenner Fiedler & Associates
13824 Bentley Place
Cerritos, CA. 90701
Ph: 213/404-2721
Ph: 800/843-5558
Fax: 213/404-7975

Wainbee Limited
215 Brunswick Blvd.
Pointe Claire, Quebec
Canada H9R 4R7
Ph: 514/697-8810
Fax: 514/-697-3070

Wainbee Limited
5789 Coopers Ave.
Mississauga, Ontario
Canada L4Z 3S6
Ph: 416/243-1900
Fax: 416/243-2336

Japan Machinery
Central PO Box 1451
Toyko 100-91, Japan
Ph: 813 3573-5421
Fax: 813 3571-7896

Gast Manufacturing Co. Ltd.
Halifax Road, Cressex Estate
High Wycombe, Bucks HP12 3SN
England
Ph: 44 494 523571
Fax: 44 494 436588

Safety

⚠ This is the safety alert symbol. When you see this symbol, personal injury is possible. The degree of injury is shown by the following signal words:

⚠ DANGER: Severe injury or death will occur if hazard is ignored.

⚠ WARNING: Severe injury or death can occur if hazard is ignored.

⚠ CAUTION: Minor injury or property damage can occur of hazard is ignored.

Review the following information carefully before operating.

General Information

⚠ DANGER: Do not pump flammable or explosive gases or operate in an atmosphere containing them. Ambient temperature for normal operation should not exceed 40 degrees C (105 degrees F). For higher ambient operation, consult the factory. Blower performance is reduced by the lower atmospheric pressure of high altitudes. If it applies to this unit, consult a Gast distributor or the factory for details.

Installation

⚠ WARNING: Electric Shock can result from bad wiring. Wiring must conform to all required safety codes and be installed by a qualified person.

Grounding is required.

The Gast Regenair blower can be installed in any position. The flow of cooling air over the blower and motor must not be blocked.

PLUMBING - The threaded pipe ports are designed as connection ports only and will not support the plumbing. Be sure to use the same or larger size pipe and fittings to prevent air flow restriction and over-heating of the blower. When installing plumbing, be sure to use a small amount of pipe thread lubricant. This protects the threads in the aluminum blower housing. Dirt and chips, often found in new plumbing, should not be allowed to enter the blower.

NOISE - To reduce noise and vibration, the unit should be mounted on a solid surface that will not increase sound. The use of shock mounts or vibration isolation material is recommended. If needed, inlet or discharge noise can be reduced by attaching muffler assemblies (see accessories).

ROTATION - The Gast Regenair blower should only rotate clockwise as viewed from the electric motor side. This is marked with an arrow in the casting. Proper rotation can be confirmed by checking air flow at the IN and OUT ports. On blowers powered by a three phase motor, rotation is reversed by changing any two of the three power wires.

Operation

⚠ WARNING: Solid or liquid material exiting the blower or piping can cause eye damage or skin cuts. Keep away from air stream.

⚠ CAUTION: Attach blower to solid surface before starting. Prevent injury or damage from unit movement.

Air containing solid particles or liquid must pass through a filter before entering the blower (see accessories list for filter suggestions). Blowers must have mufflers, filters, other accessories and all piping attached before starting. Any foreign material passing through the blower may cause internal damage.

⚠ CAUTION: Outlet piping can burn skin. Guard or limit access.

Mark "CAUTION Hot surface. Can cause burns."

Air temperature increases when passing through the blower. When run at duties above 50 in. H_2O, metal pipe may be required for hot exhaust air.

The blower must not be operated above the limits for continuous duty. 'Standard' R1, R2, R3 and R4 can operate continuously with not air flowing through the blower. Other units can only be run at the rating shown on the model number label. Do *not* close off inlet (for vacuum) or exhaust (for pressure) to reduce extra air flow. This could cause added heat and motor load.

ACCESSORIES - Gast pressure gauges AJ496 or AE133 and vacuum gauges AJ497 or AE134 show blower duty. The Gast pressure/vacuum relief valve, AG258, will limit the operating duty by admitting or relieving air. It also allows full flow through the blower when the relief valve closes.

Servicing

⚠ WARNING: Disconnect electric power before servicing. Be sure rotating parts have stopped. Electric shock or severe cuts can result. Inlet and exhaust filters need occasional cleaning or replacement of the elements. Failure to do so will result in more pressure drop, reduced air flow and hotter operation. The outside of the unit requires cleaning of dust and dirt. The inside of the blower also may need cleaning to remove material coating the impeller and housing. If not done, the buildup can cause vibration, hotter operation and reduced flow. Noise absorbing foam in the mufflers may need replacement.

KEEP THIS INFORMATION WITH THE BLOWER. REFER TO IT FOR SAFE INSTALLATION, OPERATION OR SERVICE.

TROUBLESHOOTING

Symptom	*Possible Diagnosis*	*Possible Remedy*
Excess Vibration	Impeller damaged by foreign material Impeller contaminated by foreign material	Replace impeller Clean impeller, install adequate filtration.
Abnormal sound	Motor bearing failed Impeller rubbing against cover or housing	Replace bearings Repair Blower, check clearances.
Increase in sound	Foreign material can coat or destroy muffler foam.	Replace foam muffler elements, trap or filter foreign material.
Blown fuse	Electrical wiring problem	Have qualified person check fuse capacity and wiring.
Unit very hot	Running at too high a pressure or vacuum	Install a relief valve

OPERATING AND MAINTENANCE INSTRUCTIONS

SAFETY

This is the safety alert symbol. When you see this symbol personal injury is possible. The degree of injury is shown by the following signal words:

⚠ DANGER Severe injury or death will occur if hazard is ignored.

⚠ WARNING Severe injury or death can occur if hazard is ignored.

⚠ CAUTION Minor injury or property damage can occur if hazard is ignored.

Review the following information carefully before operating.

GENERAL INFORMATION

This instruction applies to the following models ONLY: R3105N-50, R4110N-50, R4310P-50, R4P115N-50, R5125Q-50, R5325R-50, R6130Q-50, R6P155Q-50, R6350R-50, R6P355R-50 and R7100R-50. These blowers are intended for use in Soil Vapor Extraction Systems. The blowers are sealed at the factory for very low leakage. They are powered with a U.L. listed electric motor Class 1 Div. 1 Group D motors for Hazardous Duty locations. Ambient temperature for normal full load operation should not exceed 40° C (105° F). For higher ambient operation, contact the factory.

Gast Manufacturing Corporation may offer general application guidance: however, suitability of the particular blower and/or accessories is ultimately the responsibility of the user, not the manufacturer of the blower.

INSTALLATION

⚠ *DANGER Models R5325R-50, R6130Q-50, R6350R-50, R5125Q-50, R6P155Q-50, R6P355R-50 AND R7100R-50 use Pilot Duty Thermal Overload Protection. Connecting this protection to the proper control circuitry is mandated by UL674 and NEC501. Failure to do so could/may result in a EXPLOSION. See pages 3 and 4 for recommended wiring schematic for these models.*

WARNING Electric shock can result from bad wiring. A qualified person must install all wiring, conforming to all required safety codes. Grounding is necessary.

WARNING This blower is intended for use on soil vapor extraction equipment. Any other use must be approved in writing by Gast Manufacturing. Corp. Install this blower in any mounting position. Do not block the flow of cooling air over the blower and motor.

PLUMBING - Use the threaded pipe ports for connection only. They will not support the plumbing. Be sure to use the same or larger size pipe to prevent air flow restriction and overheating of the blower. When installing fittings, be sure to use pipe thread sealant. This protects the threads in the blower housing and prevents leakage. Dirt and chips are often found in new plumbing. Do not allow them to enter the blower.

NOISE - Mount the unit on a solid surface that will not increase the sound. This will reduce noise and vibration. We suggest the use of shock mounts or vibration isolation material for mounting.

ROTATION - The Gast Regenair Blower should only rotate clockwise as viewed from the electric motor side. The casting has an arrow showing the correct direction. Confirm the proper rotation by checking air flow at the IN and OUT ports. If needed reverse rotation of three phase motors by changing the position of any two of the power line wires.

OPERATION

⚠ *WARNING Solid or liquid material exiting the blower or piping can cause eye damage or skin cuts. Keep away from air stream.*

⚠ *WARNING - Gast Manufacturing Corporation will not knowingly specify, design or build any blower for installation in a hazardous, combustible or explosive location without a motor conforming to the proper NEMA or U. L. standards.* Blowers with standard TEFC motors should never be utilized for soil vapor extraction applications or where local state and/or Federal codes specify the use of explosion-proof motors (as defined by the National Electric Code, Articles 100,500 c1990).

⚠ *CAUTION Attach blower to solid surface before starting to prevent injury or damage from unit movement.* Air containing solid particles or liquid must pass through a filter before entering the blower. Blowers must have filters, other accessories and all piping attached before starting. Any foreign material passing through the blower may cause internal damage to the blower.

⚠ *CAUTION Outlet piping can burn skin. Guard or limit access.* Mark *"CAUTION Hot Surface. Can Cause Burns".* Air temperature increases when passing through the blower. When run at duties above 50 in. H_2O metal pipe may be required for hot exhaust air. The blower must not be operated above the limits for continuous duty. Only models R3105N-50, R4110N-50 and R4310P-50 can be operated continuously with no air flowing through the blower. Other units can only be run at the rating shown on the model number label. Do not Close off inlet (for vacuum) to reduce extra air flow. This will cause added heat and motor load. Blower exhaust air in excess of 230°F indicates operation in excess of rating which can cause the blower to fail.

ACCESSORIES ...Gast pressure gauge AJ496 and vacuum gauges AJ497 or AE134 show blower duty. The Gast pressure/vacuum relief valve, AG258, will limit the operating duty by admitting or relieving air. It also allows full flow through the blower when the relief valve closes.

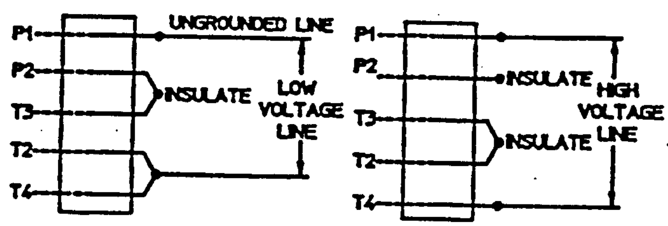
SERVICING

⚠ *WARNING To retain their sealed construction they should be serviced by Gast authorized service centers ONLY.* These models are sealed at the factory for very low leakage.

⚠ *WARNING Turn off electric power before removing blower from service. Be sure rotating parts have stopped. Electric shock or severe cuts can result.* Inlet and exhaust filters attached to the blower may need cleaning or replacement of the elements. Failure to do so will result in more pressure drop, reduced air flow and hotter operation of the blower. The outside of the unit requires cleaning of dust and dirt. The inside of the blower also may need cleaning to remove foreign material coating the impeller and housing. This should be done at a Gast Authorized Service Center. This buildup can cause vibration, failure of the motor to operate or reduced flow.

KEEP THIS INFORMATION WITH THIS BLOWER. REFER TO IT FOR SAFE INSTALLATION, OPERATION OR SERVICE.

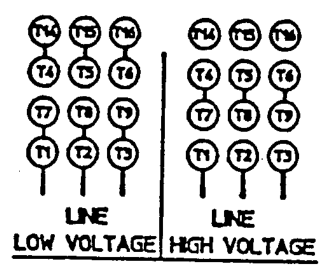
MOTOR WIRING DIAGRAM FOR R4110N-50 & R3105N-50



>>* WARNING
THIS MOTOR IS THERMALLY PROTECTED AND WILL AUTOMATICALLY RESTART WHEN PROTECTOR RESETS. ALWAYS DISCONNECT POWER SUPPLY BEFORE SERVICING.

MOTORS WIRING DIAGRAM FOR R4310P-50

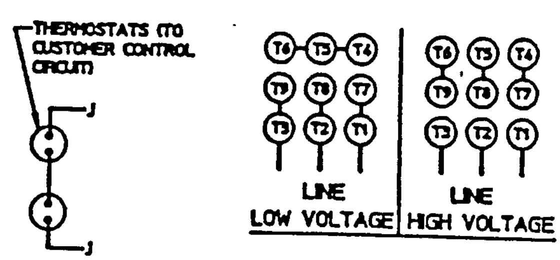
TO REVERSE ROTATION, INTERCHANGE THE EXTERNAL CONNECTIONS TO ANY TWO LEADS.



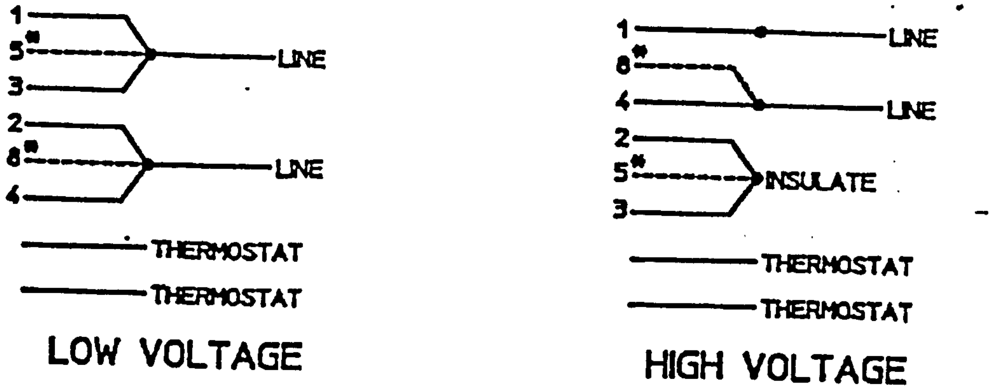
>>* WARNING
THIS MOTOR IS THERMALLY PROTECTED AND WILL AUTOMATICALLY RESTART WHEN PROTECTOR RESETS. ALWAYS DISCONNECT POWER SUPPLY BEFORE SERVICING.

MOTORS WIRING DIAGRAM FOR R5325R-50, R6350R-50, R6P355R-50, & R7100R-50

TO REVERSE ROTATION, INTERCHANGE THE EXTERNAL CONNECTIONS TO ANY TWO LEADS.



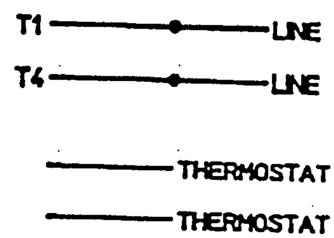
MOTOR WIRING DIAGRAM FOR R5125Q-50 & R4P115N-50



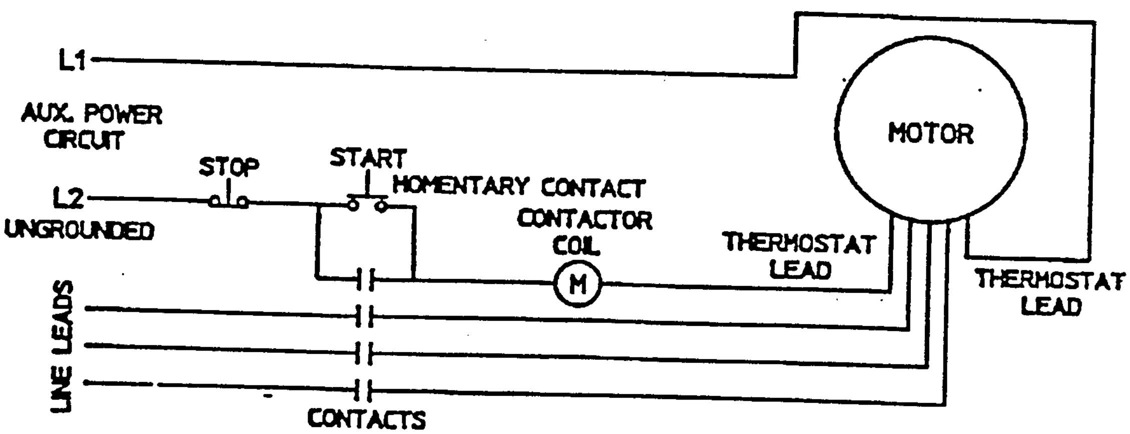
* R5125Q-50 BLOWERS PRODUCED AFTER SEPTEMBER 1992 (SER. NO. 0992) DO NOT HAVE MOTOR LEADS 5 & 8.

MOTOR WIRING DIAGRAM FOR R6130Q-50 & R6P155Q-50

CONNECT THERMOSTAT TO MOTOR PROTECTION CIRCUIT



CONNECTION FOR THERMOSTAT MOTOR PROTECTION



TERMOSTATS TO BE CONNECTED IN SERIES WITH CONTROL AS SHOWN. MOTOR FURNISHED WITH AUTOMATIC THERMOSTATS RATED A.C. 115-600V. 720VA

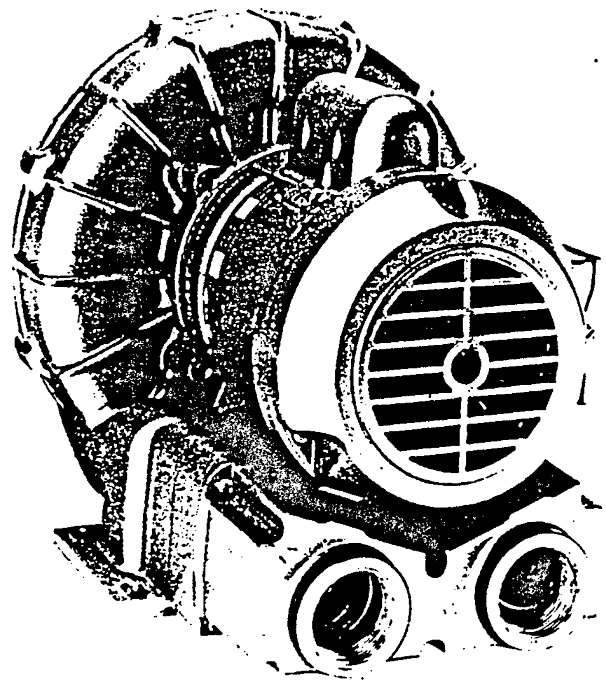
AK811 rev. E

Oilless Regenerative Blowers, Motor Mounted to 92 cfm

GAST

PRESSURE

REGENAIR® R4 Series



MODEL R4110-2

52" H_2O MAX. PRESSURE, 92 CFM OPEN FLOW

PRODUCT FEATURES

- Oilless operation
- TEFC motor mounted
- Can be mounted in any plane
- Rugged construction/low maintenance
- Can be operated blanked-off

COMMON MOTOR OPTIONS

- 115/208-230V, 60 Hz; 110/220-240V, 50 Hz, single phase
- 208-230/460V, 60 Hz; 190-230/380-415V, 50 Hz, three phase
- 575V, 60 Hz, three phase

RECOMMENDED ACCESSORIES

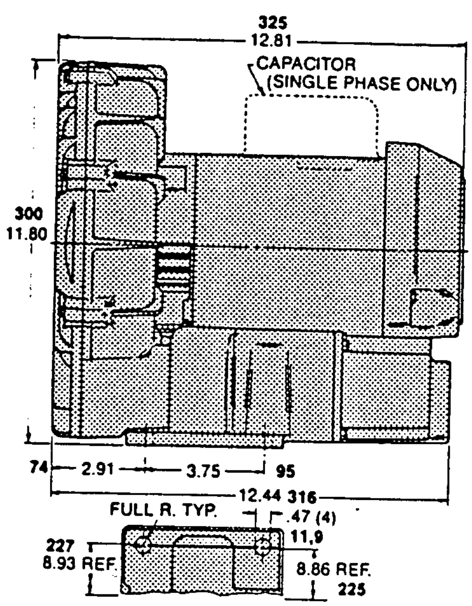
- Pressure gauge AJ496
- Filter AG338
- Muffler AJ121D
- Relief valve AG258

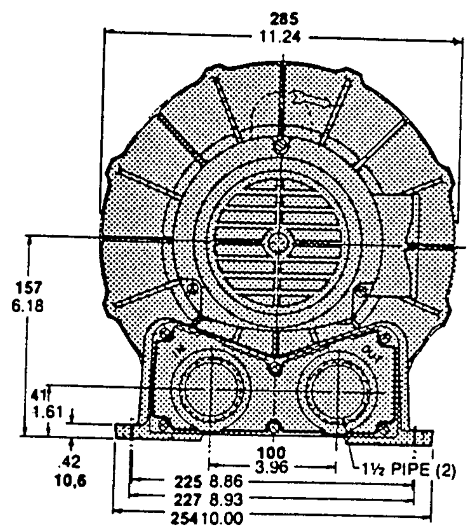
Various brand name motors are used on any model at the discretion of Gast Mfg. Corp.

Important Notice:

Pictorial and dimensional data is subject to change without notice.

Product Dimensions Metric (mm) U.S. Imperial (inches)



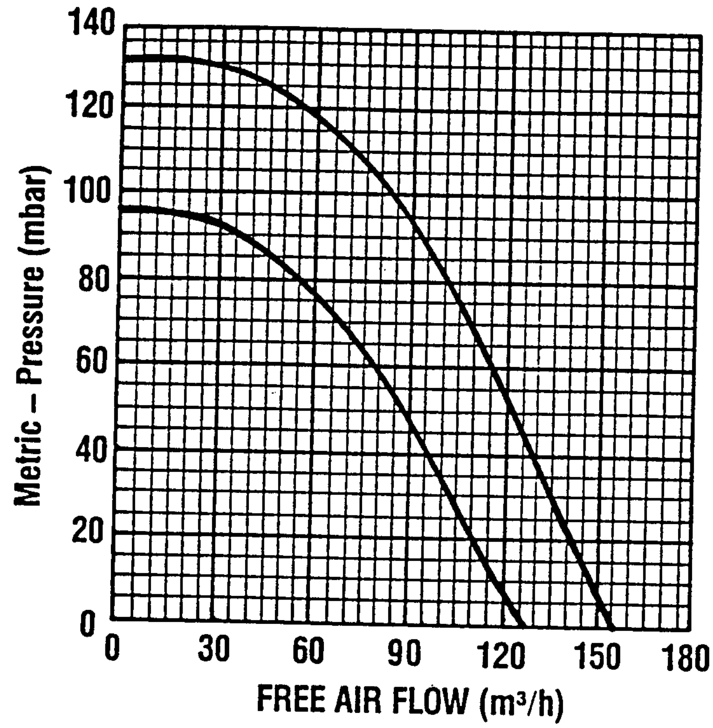


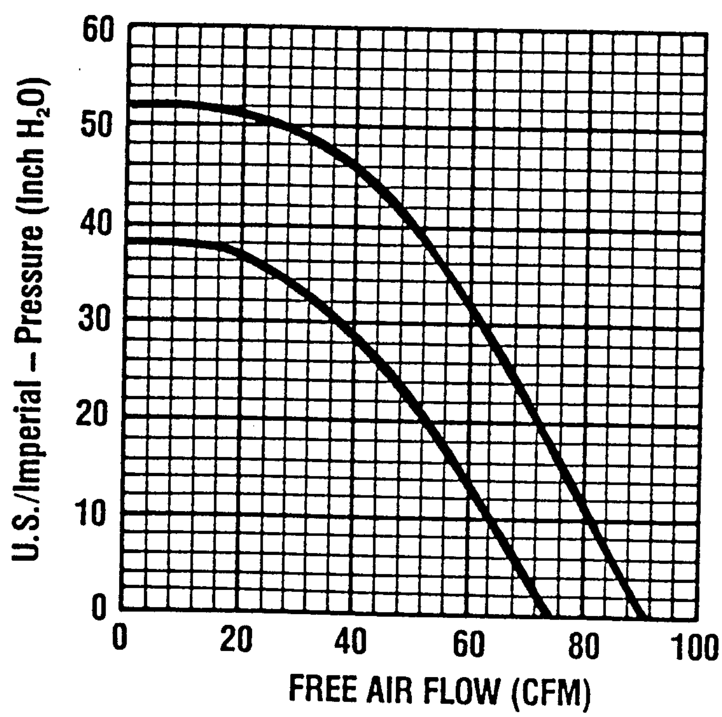
Product Specifications

Model Number	Motor Specs	Full Load Amps	HP	RPM	Max Pressure "H_2O	Max Pressure mbar	Max Flow cfm	Max Flow m^3h	Net Wt. lbs.	Net Wt. kg
R4110-2	110/220-240-50-1	9.0/4.5-5.7	0.6	2850	38	95	74	126	41	18,6
	115/208-230-60-1	9.8/5.2-4.9	1.0	3450	52	130	92	156		
R4310A-2	190-220/380-415-50-3	2.6-3.3/1.3-1.4	0.6	2850	38	95	74	126	41	18,6
	208-230/460-60-3	3.4-3.2/1.6	1.0	3450	52	130	92	156		

Product Performance (Metric U.S. Imperial)

Black line on curve is for 60 cycle performance.
Blue line on curve is for 50 cycle performance.

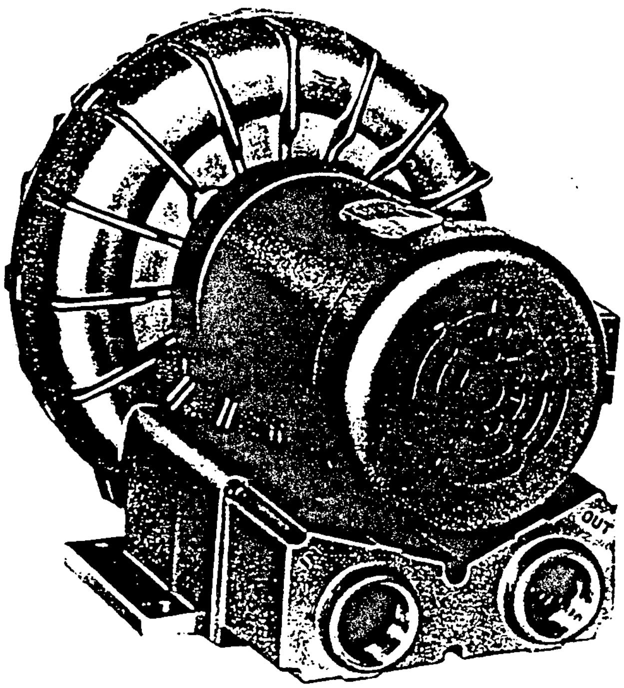




Oilless Regenerative Blowers, Motor Mounted to 160 cfm

GAST

REGENAIR® R5 Series



MODEL R5325A-2
65" H_2O MAX. PRESSURE, 160 CFM OPEN FLOW

PRODUCT FEATURES

- Oilless operation
- TEFC motor mounted
- Can be mounted in any plane
- Rugged construction/low maintenance

COMMON MOTOR OPTIONS

- 115/208-230V, 60 Hz, single phase
- 208-230/460V, 60 Hz; 190-220/380-415V, 50 Hz, three phase
- 575V, 60 Hz, three phase

RECOMMENDED ACCESSORIES

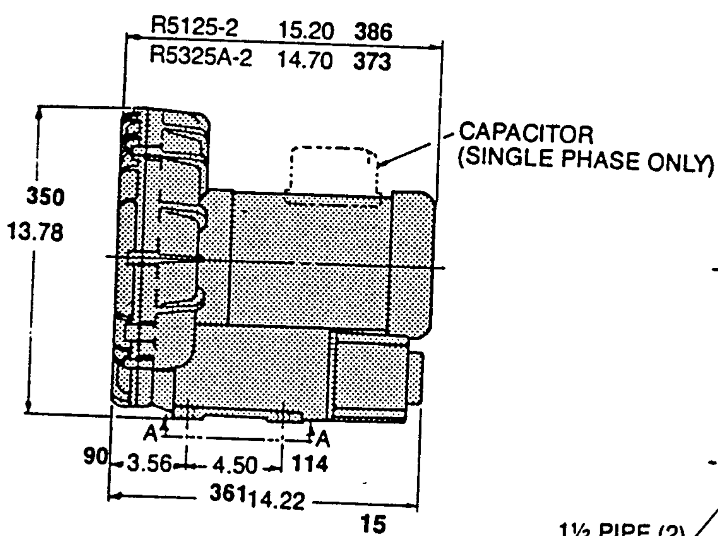
- Pressure gauge AE133
- Filter AG338
- Muffler AJ121D
- Relief valve AG258

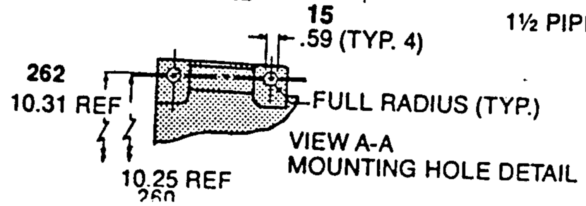
Various brand name motors are used on any model at the discretion of Gast Mfg. Corp.

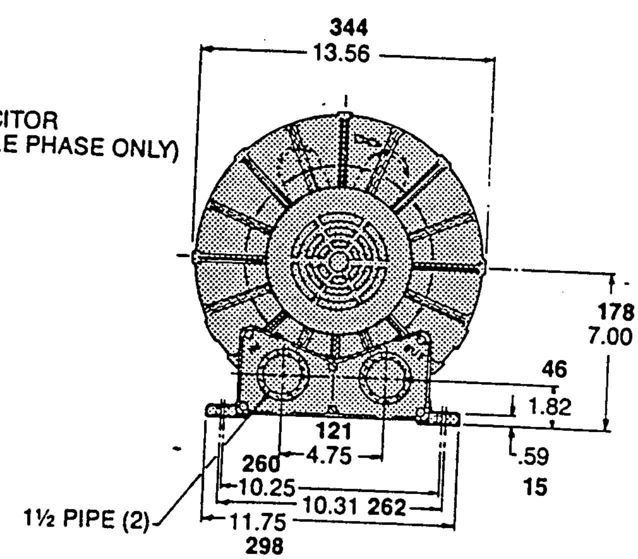
Important Notice:

Pictorial and dimensional data is subject to change without notice.

Product Dimensions Metric (mm) U.S. Imperial (inches)





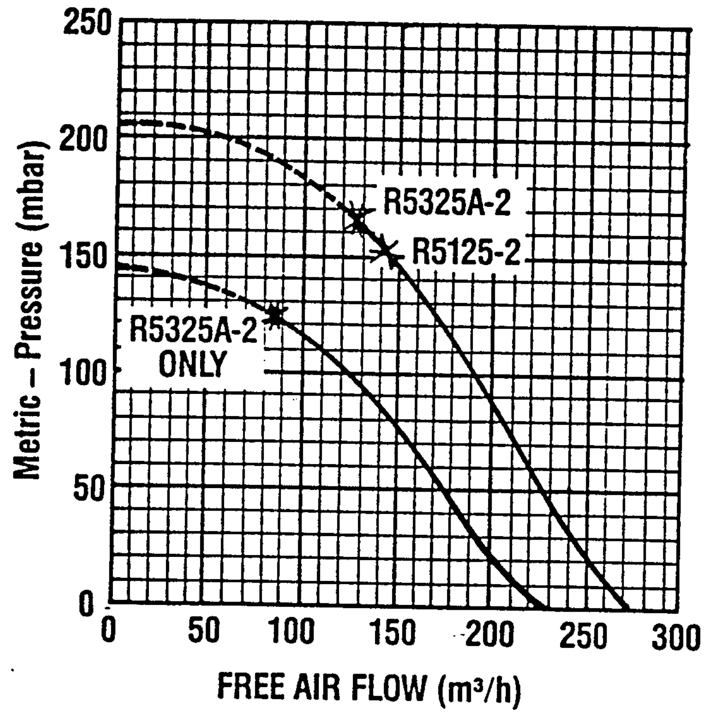


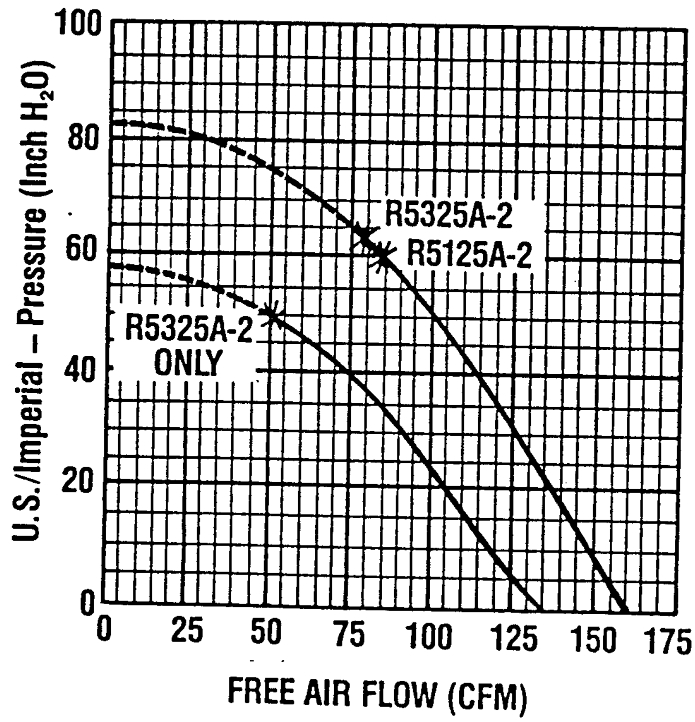
Product Specifications

Model Number	Motor Specs	Full Load Amps	HP	RPM	Max Pressure		Max Flow		Net Wt.	
					"H_2O	mbar	cfm	m³h	lbs.	kg
R5325A-2	190-220/380-415-50-3	6.6-6.7/3.3-3.5	1.35	2850	50	125	133	226	65	29,5
	208-230/460-3	6.9/3.45	2.5	3450	65	162	160	272		
R5125-2	115/208-230-60-1	22.4/12.4-11.2	2.5	3450	60	149	160	272	73	33,1

Product Performance (Metric U.S. Imperial)

Black line on curve is for 60 cycle performance.
Blue line on curve is for 50 cycle performance.





*Recommended maximum duty.
- - - - Intermittent duty only.

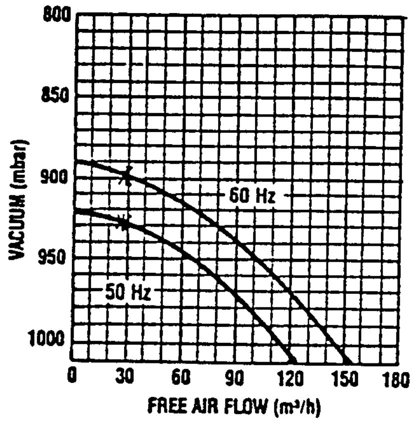
Product Specifications

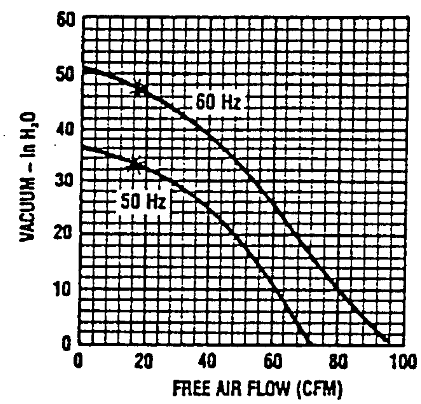
Model Number	Hz	Motor Specs	HP	RPM	Max Vac "H₂0	Max Vac mbar	Max Flow cfm	Max Flow m³h	Net Wt. lbs.	Net Wt. kg
R4110N-50	50	110/220-240-50-1	0.6	2850	35	924	72	122	60	28
	60	115/208-230-60-1	1.0	3450	48	895	88	150		
R4310P-50	50	220/380-50-3*	0.6	2850	35	924	72	122	58	27
	60	208-230/460-60-3*	1.0	3450	48	895	88	150		
R5125Q-50	60	115/230-60-1*	2.5	3450	60	865	145	246	77	35
R5325R-50	50	190-220/380-415-50-3*	1.85	2850	47	897	120	204	75	34
	60	208-230/460-60-3*	2.50	3450	60	865	145	246		
R6P355R-50	50	190-220/380-415-50-3*	4.5	2850	70	840	235	400	247	112
	60	208-230/460-60-3*	6.0	3450	90	790	260	442		

*Motors do not have thermal protection with automatic reset.

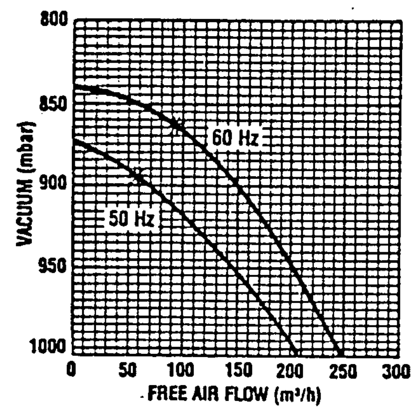
Product Performance (Metric U.S. Imperial)

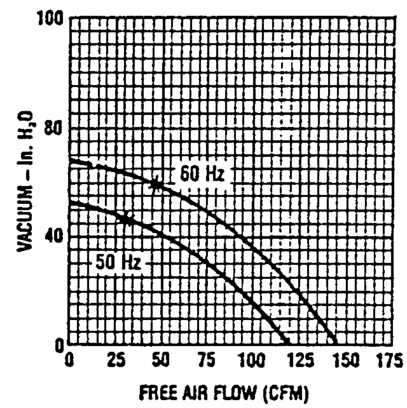
Model R4 Series



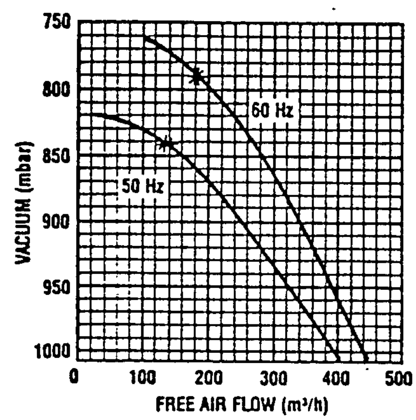


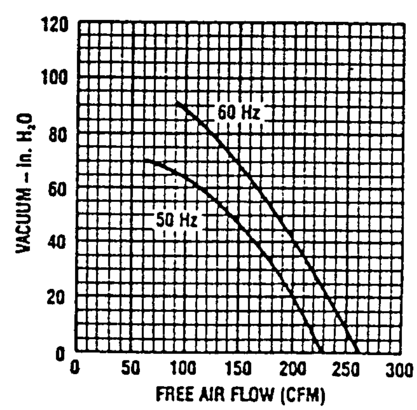
Model R5 Series





Model R6P Series





*Minimum flow permissible through the unit for trouble-free, continuous operation.